TEXTILES ON TEST

J. GUILFOYLE WILLIAMS

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TEXTILES ON TEST

A STUDY
FOR DISTRIBUTOR AND CONSUMER OF
THE WEARING AND WASHING PROPERTIES
OF FABRICS AND GARMENTS

By

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WITH A FOREWORD BY

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FOREWORD

THE confidence and future goodwill of customers depend largely upon the satisfaction-giving qualities of merchandise offered to them by the distributing house or shop, and it therefore becomes extremely necessary that the heads of all such businesses make themselves as well-informed as possible regarding the real qualities of the merchandise which they are selling. Anything which assists in giving to them this knowledge is desirable.

This book has been patiently and carefully prepared. It is a study of the wearing and washing qualities of textile merchandise, written primarily for the information of the proprietors of retail distributing houses and their staffs and of shopkeepers generally. It is also of great value to manufacturers, and is not without interest to the general consuming public. It is based on wide practical experience in the examination of merchandise for retail distribution and consumption, as well as upon a scientific study and knowledge of textiles.

I recommend it, therefore, to all who are associated with retail distribution, with production, or even with consumption, and especially I do so in my desire to see the great business of Retail Distribution build itself more and more into a recognised position, offering opportunities as a career to the growing youth of the land.

H. GORDON SELFRIDGE.

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TEXTILES ON TEST

CHAPTER I

INTRODUCTION

THIS book is a study of textiles from a new angle. It is concerned with the satisfaction and service rendered by textile merchandise. Every care has been taken to make it authoritative, and yet clear and intelligible to everyone.

Perfection is approached by the realisation and the removal of imperfections, and for this reason it has been necessary particularly to discuss the defects of textile merchandise. But the whole object of this book is to be constructive. A carefully considered suggestion which should benefit the whole of the textile industry is given in the concluding chapter. And so far as the distributor and consumer are concerned simple and practicable methods for testing textiles have been given wherever possible.

In view of this discussion of defects, members of the general public may form an incorrect opinion of the service rendered by retail distributors, and so a few remarks on this point are necessary. In the first place the duty of the distributor is to satisfy the public demand, and the measure of his success in this may be judged from the fact that complaints against the qualities of textile merchandise are much less than one per thousand transactions. Moreover, the merchant

can only select the goods produced by manufacturers. In this selection he can usually only rely on the statements made to him, and checked so far as possible by his own knowledge and experience, for in the general case it is not practicable for him to secure scientific tests.

The distributor, however, is anxious for progress and improvement, for the policy of many distributing houses is to render the utmost service to the customer, and to secure his or her implicit confidence. The general zest for helpful knowledge has been very evident in the close attention paid to the lectures the author has given at the Drapers' Summer Schools of 1928, 1929, and 1930, and in the keenness of the discussions which have followed. The scientific testing departments that form part of the organisation of a number of large distributing houses in this country and in the United States of America are an example of direct expenditure for the improvement of merchandise qualities.

It is hoped that this book will prove helpful to all parties concerned with textiles. To the manufacturer it gives useful information arising from a careful study of textile merchandise from the consumer's point of view. To the distributor it gives exact technical information on many questions that beset him in buying and in selling. To the customer it gives guidance both in the buying and in the subsequent use of textile merchandise.

No section of this book deals specifically and in detail with any one textile fibre or manufacturing operation. There are already many books dealing with the individual fibres, and the bibliography of textile manufacturing processes is immense. Nor

does the book deal with the particular structures and general qualities of different types of fabrics. But by reference to the index the various pages dealing with questions affecting any one fibre may be ascertained. Arising from this one caution is necessary. Comparisons of the durability or wear resistance of textile products are not the sole criteria in buying; æsthetic considerations are of great importance. For instance, linen is much less resistant than cotton to laundering, but the smoothness, lustre and beauty of fine linens are a source of pride and happiness to the average housewife.

The contents of this book are divided into sections, each of which covers the main ground concerning some aspect of textiles, but it has not proved desirable to make each section a complete and self-contained survey of that particular aspect. For a comprehensive survey of any problem, the section concerned should first be read and then other facts which are available will be found by reference to the index.

The authorities for various statements and facts have been given in footnotes to the text. The appendix contains a selected list of books of interest to distributors and consumers, and for those who desire more detailed information on special subjects a short list of references to technical literature has also been given.

The author desires to acknowledge the ready and helpful assistance he has always received from the British Research Associations concerned with textiles. For reading this book in the proof state, and offering criticisms and suggestions, his thanks are due to: The Directors of the Research Associations for Laundering, Linen, Silk and Wool; Mr. J. H. Lester, M.Sc., F.I.C., Technologist, Tootal Broad-

hurst Lee Co., Ltd., Manchester, and fomerly Manager of the Testing House of the Manchester Chamber of Commerce; Mr. J. M. Evans, Dyeing and Finishing Department, Marling & Evans, Ltd., Stroud, Glos.; Mr. J. Blair, B.Sc., of the Clayton Aniline Co., Ltd.

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The author is also indebted to Mr. A. B. Moss and Mr. R. S. Cappell for a number of excellent photographs of samples.

CHAPTER II

GENERAL FACTS CONCERNING FABRICS

Section 1

Composition.—One of the first considerations in the buying or the selling of a fabric is its composition. It is obvious that descriptions such as " all silk " or " Botany wool " must be correct if trading is to be fair. Moreover, from the point of view of the vendor they must be correct to remove risk of undesirable publicity arising from legal proceedings under the Merchandise Marks Acts or the Sale of Goods Act.

Concerning silk, definitions have been made by the Silk Association of Great Britain,[1] and these are :

> *Silk* is the natural product of the silkworm, whether nett or spun : goods or articles made therefrom may be called silk only if they contain no other fibres.
>
> *Pure silk* is applied to goods that contain no weighting other than that arising essentially from dyeing and finishing.
>
> *In mixtures* the use of the term silk must be qualified such as " silk union," " silk warp poplin," and the like.

This means that weighted silk can be described as " silk " or " all silk," but not as " pure silk."

In regard to the description " all wool," there is an opinion among some folk that by virtue of some trade custom the presence of small amounts of cotton, say

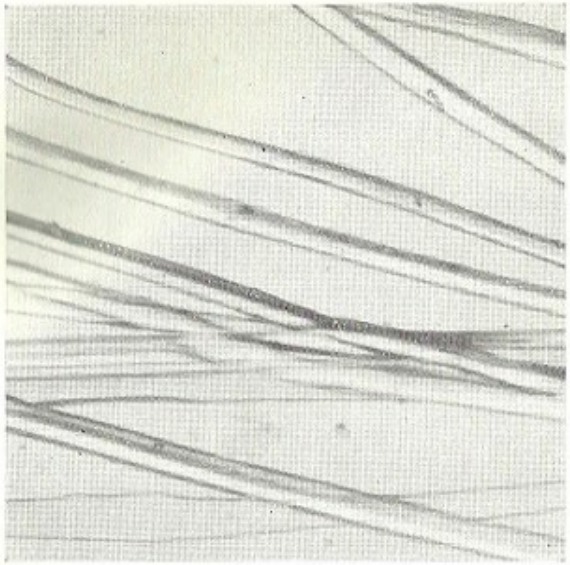
[1] *Times Trade Supplement*, 1923. Vol. 12. No. 255, p. 244.

3% to 5%, is permissible. This is wrong; goods described as "all wool" must be all wool.[1] Again, wool goods may be described as merino, Botany, worsted, virgin, or pure. Definite meanings are attached to these terms; for instance, merino or Botany wools must be of a certain fineness, worsted yarns differ from woollen yarns and are more expensive, and virgin wool must clearly not include recovered wool (shoddy).

Some people consider that the description of a cloth as "woollen" does not mean it need be all wool, and it is even suggested that the term "woollen" may be interpreted as "wool-like," and so a wool-like fabric may be termed "woollen" although it contains no wool. Such descriptions will certainly not be used by reputable traders, for in any case they are deceptive, and it is probable that a test case would prove them to be illegal.

In place of the description "artificial silk" the term "rayon" is now widely used. This clearly distinguishes the product from silk to which it has no relationship except of a very superficial character; in chemical constitution and physical properties rayons are quite distinct from silk. For this reason the description "synthetic silk" for rayons is false and objectionable. A synthetic product is one made by chemical processes but identical in chemical constitution and physical properties with the natural product. Equally the description "art. silk" is objectionable; the word "art." is not a universally recognised contraction of the word "artificial."

[1] Query: "What maximum percentage of cotton, if any, is permitted in a cloth reasonably to be described as 'all wool'?" addressed to the Bradford Chamber of Commerce. Reply of March 20, 1929, states: "Any cloth containing whatever percentage of cotton cannot be described as 'all wool.'"



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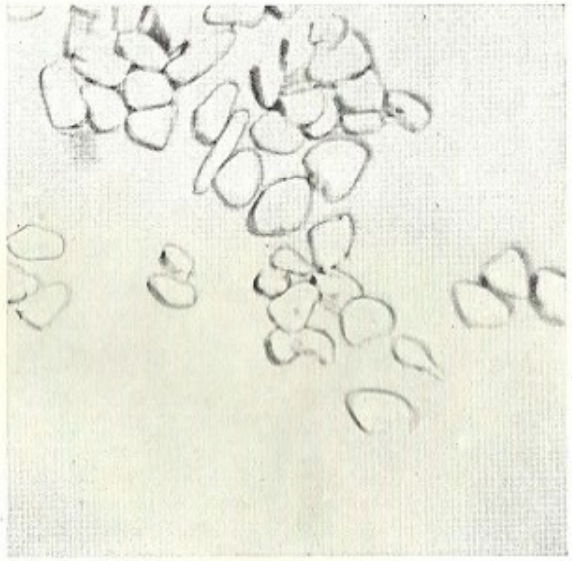

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Fig. 1.—Photomicrographs of silk fibres in length and cross section.

(*Courtesy of the British Silk Research Association.*)

[*To face page* 6.

a smooth surface produced by passing the yarn over gas jets."

Finally it is, at the least, desirable that rayon fabrics shall be distinguished as to type. Cellulose acetate rayon is very different from ordinary cellulose rayon (produced by the viscose, nitro-cellulose or cuprammonium processes) in that it dyes differently, is dissolved by organic solvents such as acetic acid, chloroform, or acetone, loses its lustre if boiled or washed at a high temperature, and melts if pressed with a hot iron. If the public buy material simply as rayon, they have good grounds for complaint if one rayon fabric withstands certain treatments such as hot wash and hot ironing, and another product sold under the same description is spoiled or destroyed by such treatments.

In cases of misdescription it is open to any private person to take proceedings under the Merchandise Marks Acts, or a complaint may be lodged with the Board of Trade, and if the matter is of sufficient public importance this body will undertake proceedings. More usually in serious misdescriptions it will be found that the Trade Associations concerned are the bodies that take action. In case of any doubts concerning correct descriptions, anyone may write to the Board of Trade and secure its ruling on the matter.

Now for the problem of verifying descriptions.

To be definite concerning composition there must be recourse to scientific tests, and it cannot be stated too emphatically that simple tests are not enough. When deliberate fraud is attempted by immoral but competent people their first consideration is that the product must respond satisfactorily to all simple tests.

Some simple tests are, however, very desirable in

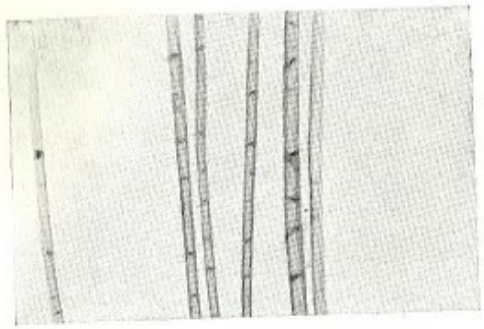

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Fig. 4.—Photomicrograph of bleached linen fibres.

(Courtesy of the British Linen Industry Research Association.)

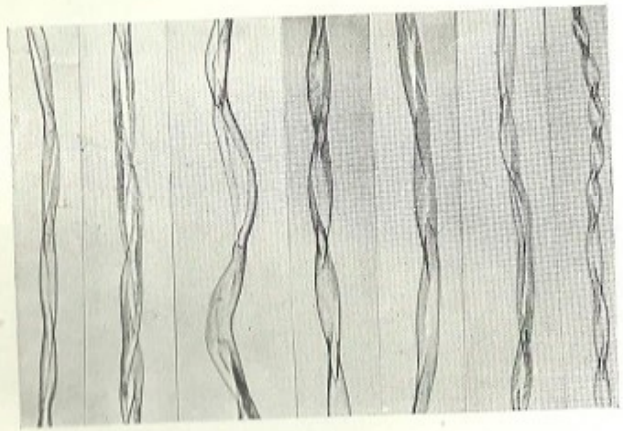

Fig. 5.—Photomicrographs of various cotton fibres, showing the convolutions.

(Courtesy of the British Cotton Industry Research Association.)

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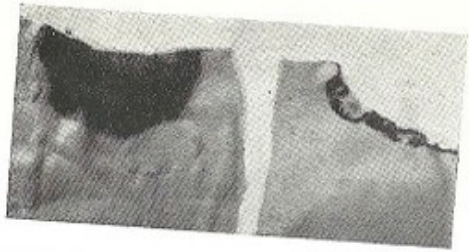

Fig. 6.—Photograph showing the difference between burned mineral weighted silk and burned pure silk.

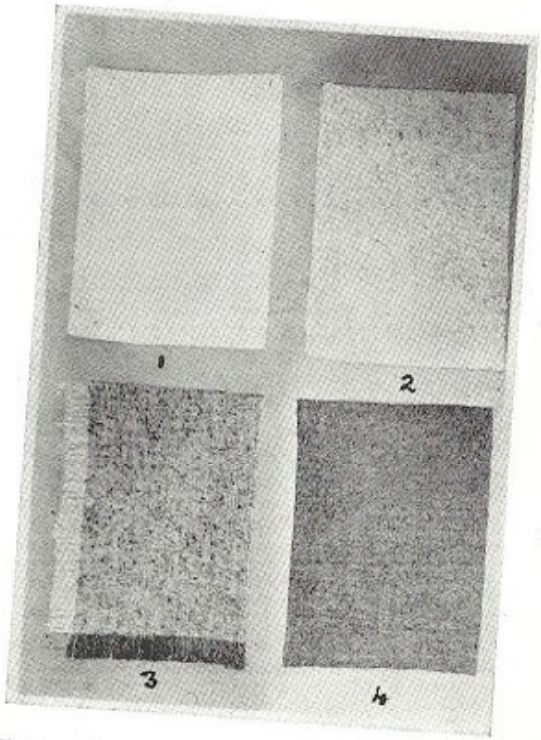

Fig. 7.—Fabrics submitted to the plumbate staining test for wool. (1) winceyette (no wool content); (2) wincey containing 3·4% of wool; (3) wincey containing 22% of wool and dissected to show wool is only in one set of the threads; (4) wincey containing 60% of wool.

[*To face page* 9.

buying, for they will give much more effective guidance than will appearance and handle.

The first test is the burning test. Take separately warp threads and weft threads. Carefully untwist each of these threads to ascertain if two or more yarns have been twisted to make the thread, and if so divide the thread into its constituent yarns. Apply a lighted match to one end of the yarn, note how the yarn burns, then blow out the flame and smell the fumes given off by the smouldering material. Material that flames readily and gives a smell like burned paper will be rayon or vegetable fibre (cotton, linen, hemp, jute, etc.). Cellulose acetate also burns fairly readily, but not quite so easily as cotton, linen or cellulose rayon; in burning, the yarns melt back (like sealing wax) and the ends of the extinguished yarns will have hard, black globules. The fumes have a faint vinegar-like smell. Material that flames with difficulty, apparently melting back and giving fumes that smell like burned feathers, will be silk or wool. In the case of mineral weighted silk the yarn may only char, leaving a black ash, clearly showing the original thread, and the fumes may only smell very faintly of burned feathers. The difference between burned pure silk fabric and mineral weighted silk fabric is illustrated in Fig. 6.

The remaining tests require simple chemicals. When cellulose acetate yarns are wetted with glacial acetic acid, or with acetone, they dissolve or become sticky; all other fibres are unaffected. When ordinary silk yarns are placed in cold concentrated hydrochloric acid (spirits of salt) and left for five minutes they dissolve if pure silk, or if mineral weighted silk they leave a gelatinous mass possessing no

strength; wild silk (tussore or shantung) and wool are not apparently affected. When wool is boiled for five minutes in a ten per cent. solution of caustic potash it is decomposed and dissolves; ordinary silk is also dissolved, but other fibres are not appreciably affected. Finally, in fabrics containing a mixture of wool and other fibres it is possible to detect wool by a simple test. When a lead acetate solution is added to hot ten per cent. caustic potash solution until a permanent precipitate is formed a solution of potassium plumbate is obtained. This solution should be diluted to ten times the original volume of the caustic potash solution and filtered. If fabric is boiled in this solution for one minute, then any wool present will become brown or black and so show distinctly even if only present to the extent of two or three parts per hundred. The effect is illustrated in Fig. 7.

These tests are set forth in Table No. I, and the application of the tests in the order set out will give very useful guidance.

In the case of need for distinction between cotton, linen, and hemp, a simple test[1] gives very definite results. The yarn in question is well wetted, and then single fibres are pulled out, using the thumb and index finger. The loose end of the fibre should be towards the observer, and it will be noticed that almost immediately this end will commence to move. With linen the rotation is clockwise (in the direction of the hands of a clock), with hemp it is counter clockwise, and with cotton it is an irregular movement. This test requires some practice before it can be performed

[1] Nodder. Journal of the Textile Institute. 1922. Vol. 13, p. T161.

TABLE NO. I

Simple tests for composition of fabrics.

1. Burn yarns extracted from the fabric. There are three possibilities—

(a)		(b)		(c)
Burns readily. After extinction fumes smell of—		Burns with difficulty. After extinction fumes smell of burned feathers, soft black globules left.		Chars and leaves a black ash, showing the original yarn.
Burned paper, leaving light grey ash.	or vinegar, leaving black beads on yarns.	Now apply second tests to fresh yarns— 2. Place yarn in cold concentrated hydrochloric acid.		Dissolves in cold concentrated hydrochloric acid, leaving only an easily broken gelatinous mass.
Now apply second tests to fresh yarns— 2. Wet the yarns.	2. Spot fabric with glacial acetic acid or acetone. Becomes sticky.	Dissolves in about five minutes.	Does not dissolve. Boil in 10% caustic potash solution.	Mineral weighted silk.
Retention of strength.	Loss of strength.		Dissolves. Does not dissolve.	
Cotton, hemp or linen.	Cellulose rayon.	Unweighted silk.	Wool. Wild silk.	
	Acetate rayon.			

(for it is not easy to see the fine fibre until a suitable background and angle of illumination are secured), but it is very sure.

Simple tests fail with blended yarns. For instance, a blended yarn of rayon and silk, or cotton and wool, may not give a recognisable burned feather smell. A cotton and wool yarn containing twenty per cent. of wool will burn and smell like an all cotton yarn.

In quantitative analysis the processes used depend on the nature of the mixture, but generally one dissolves out some constituents and leaves the others to weighed. For instance, in a mixture of cotton and wool containing an appreciable amount of wool, the wool can be dissolved out by boiling in caustic potash, and the cotton can be weighed. A fabric so treated is shewn in Fig. 8. But where only a small percentage of wool is present this would not be an accurate process ; in this case the cotton is dissolved by a strong cold solution of sulphuric acid and the wool is left unaffected. With acetate rayon mixtures, the rayon can be dissolved out, using acetone. In some other cases the estimation can only be done by unravelling or by microscopical examination. This would apply to mixtures of cotton and cellulose rayon or linen.

As a conclusion to this section reference must be made to descriptions which are true but deceptive. Winceys are useful fabrics containing cotton and wool. The cost and merit are in part determined by the wool content. In fabrics containing 20% to 60% of wool some merit is secured by the presence of wool. But where only 5% of wool is present as in some low quality fabrics the term " cotton and wool mixture " is somewhat deceptive, and yet the author has examined winceys containing only 1% and 2% of wool. Again in

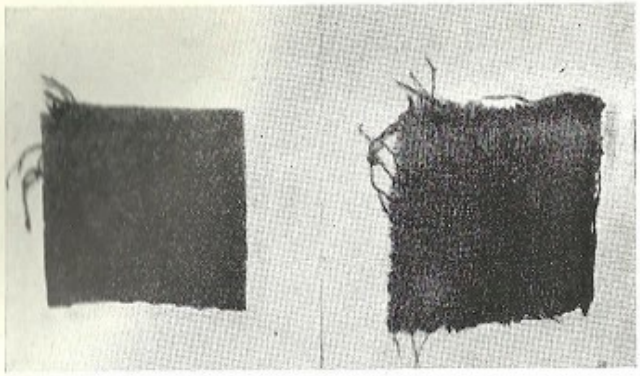

Fig. 8.—Tweed coating containing 23% of cotton before and after dissolving out the wool with caustic potash. Note the sample has enlarged somewhat when the wooi is dissolved away. The wool had been slightly felted, causing some shrinkage.

Fig. 9.—A silk and cotton union umbrella cover. The silk forms only 4% by weight of this fabric. The fine warp threads are silk yarns. They actually are single strands as reeled from the cocoon and each contains only eight silk filaments. The tensile strength on a four-inch grab test is 187 pounds for the cotton weft and 34 pounds for the silk warp.

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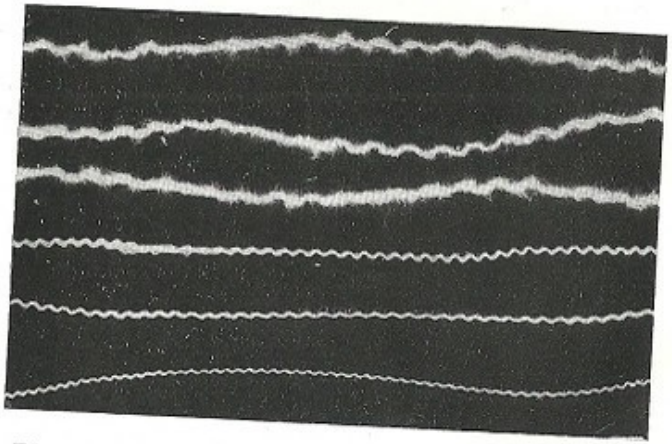

Fig. 10.—The coarse and fuzzy yarns are woollen yarns; the fine and clear yarns are worsted yarns.

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hosiery a description as "silk reinforced with rayon" is met; in many cases the silk has only formed 10%, or less, by weight of the fabric; in poor cases it has been less than 5% of the fabric. The limit is probably reached in some silk union umbrella covers. Here the warp threads are all silk and the weft threads are cotton; but by using very fine and so very weak silk threads fabrics can be produced which contain only 4% by weight of silk. One such fabric is shown in Fig. 9. The warp strength of the fabric is too low to resist normal strains in use. The fabric is unfit for sale.

Section 2

Preparation of Yarns.—The first step towards making a fabric is the conversion of a mass of fibres into yarns.

In silk or rayon the fibres may be hundreds of yards in length. By simply taking a number of these continuous fibres or filaments and uniting them by twisting yarns can be formed. This type of yarn is called a nett yarn.

Generally, however, fibres are of comparatively short lengths, say one to two inches with cotton, three to nine inches with wool, and up to twenty inches with flax. These are made into spun yarns. The exact processes are not of particular importance in this brief survey of the subject. The fibres are first separated from the tangled mass of the original material and then they are formed into a long loose roll which is about one inch in diameter. This roll of fibres is subjected to a simultaneous twisting and drawing out operation, which gives a longer and finer roll, and after many repetitions of this operation a spun yarn is the result.

There are thus two general types of yarn, the nett and the spun. In the spun yarn there is a division typified in the woollen and worsted yarns. With fine wools the separation of the fibres is continued by combing operations, and ultimately all the fibres are laid parallel to each other in the roll, and also a proportion of any short fibres present is removed by the combing operation. This combed fibre spins into a very clear, smooth yarn. The smoothness of worsted yarns compared with woollen yarns is shown in Fig. 10. The difference between a woollen yarn with the fibres irregularly intertwined and a worsted yarn with parallel fibres is easily discerned when a yarn is untwisted. In cotton a similar type of yarn is made, and it is known as combed yarn. The ordinary cotton yarns are carded yarns.

During this process of yarn manufacture, different fibres can be blended together. For instance, different qualities of wools may be blended, or some recovered wool may be mixed in, or cotton or silk may be added to the yarn. Usually the fibres are worked up in the undyed state, but in certain cases it is preferable to dye the fibre before it is spun into yarn, and of course where special effects are secured by using multi-coloured yarns (as in tweeds) it is essential to use dyed fibres in the spinning.

These single yarns may be combined to form folded or ply yarns. The finest nett silk yarn is the strand, which usually contains ten silk filaments ; the ordinary silk yarns contain a number of these strands (say six to twelve) twisted together. In combining yarns the twist applied is usually in an opposite direction from that used when spinning the yarns ; for example, if the fibres are twisted clockwise in spinning, then in

combining yarns the twist applied would be counter-clockwise. But if " hard " yarns are required the twist used is in the same direction as that in the single yarns. By untwisting yarns it is easy to see if they are folded ; for instance, spun silk yarns are usually two-fold yarns, and sewing threads are usually manifold, as say by making two-fold yarns and then retwisting three of these, so giving a yarn containing in its structure six separately twisted threads.

The special advantage of folded yarns is that they are more even in size, and in strength. In spite of the greatest of care in spinning, yarns will be somewhat uneven and, still worse, they will have weak places. These weak places mean risk of breakage during the weaving or knitting, and so the production of faulty fabric. When two yarns are twisted the weak place, in all probability, will be reinforced by a portion of normal strength. And, moreover, in wear one yarn in the thread may become worn, but the other may be unaffected. A two-fold yarn is not necessarily stronger than the combined single strengths of the two yarns from which it was made, but it is more reliable and it wears better.

There are endless possibilities in fancy or novelty yarns. Slubs are thick portions of yarns produced owing to defective spinning, but for slub reps, the popular furnishing fabric, artificial slub yarns are made by twisting two cotton threads together and occasionally introducing a third coarse yarn to form the slub. Other effects are produced by twisting two differently coloured threads together, or by having one thread very loose and bound by two taut threads.

Defective spinning may produce slubby yarns, or the yarn may have broken frequently and contain

many knots, or the yarn may be uneven, and contain thin and consequently weak places.

Section 3

Preparation of Fabrics.—The conversion of fibres into fabric can be effected either by felting (only with wool and hair), or by weaving, or by knitting, or by twisting together warp yarns as in lace-making, or by a combination of these processes. The oldest process is undoubtedly weaving, and this will be considered first.

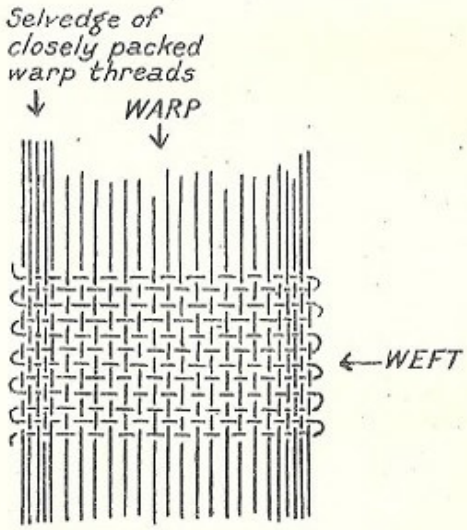
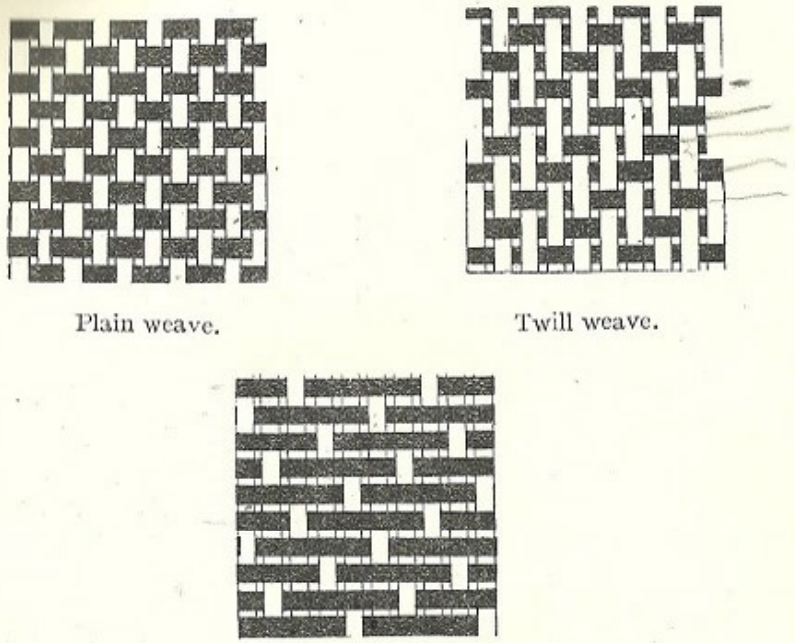


Fig. 11.—Illustration of woven fabric.

The most simple illustration of weaving is darning. In this process the first operation is to fix a number of threads parallel and close to each other, stretching across the hole. Then threads are inserted passing from side to side, at right angles to the original threads, and going alternately over and under them. This weaves a portion of fabric in the hole. In weaving, one long set of threads is fixed approximately equal in length to the fabric to be made, and running parallel to the length of the fabric. These are the warp threads. Now cross threads are inserted, so forming the cloth, and these cross threads (stretching

across the width of the fabric) are the weft threads. The illustration in Fig. 11 should help this explanation.

It is possible to secure many types of weave, but here we will only note the three illustrated in Fig. 12. The Plain or Tabby weave has the weft passing alternately under and over the warp threads. In the Twill weave, the interlacing, in place of alternately under and over, is uneven, as say under one and over two. In the Satin weave the interlacing is still less, as either under one thread and over four or over seven threads. In a special case there can be some warp or weft threads which in place of



Plain weave. Twill weave.

Satin weave.

Fig. 12.—Three types of interlacing showing the plain, twill and satin weaves.

lying flat in the fabric are raised in loops, giving pile fabrics (as say in terry towelling), or the pile may be cut, giving a velvet type of material.

The illustration in Fig. 13 clearly shows how lace fabrics are made by twisting together warp yarns.

Knit fabrics are of two types, the weft-knitted fabrics, and the warp-knitted fabrics.

In weft-knitted fabrics only one yarn is used, and this is formed into layer upon layer of loops passing

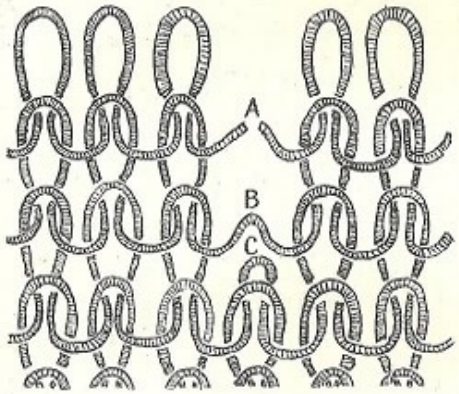


Fig. 14.—Structure and laddering of weft-knit fabric. It shows the loops made by six needles and four courses of these loops (see p. 29).

through the loops of the preceding layer, as shewn in Fig. 14. The effect of this type of fabric is that each loop is only secured by the loop above. If, for instance, the loop at A in Fig. 14 is broken, the yarn slips out with any slight strain and then the loop B is not held, and slips through the loop C, which can then slip out through the loop below, and so on, producing that well-known bugbear, a "ladder." It will also be seen that if the knit fabric is made of smooth yarns, as silk or rayon, laddering can easily occur, but with

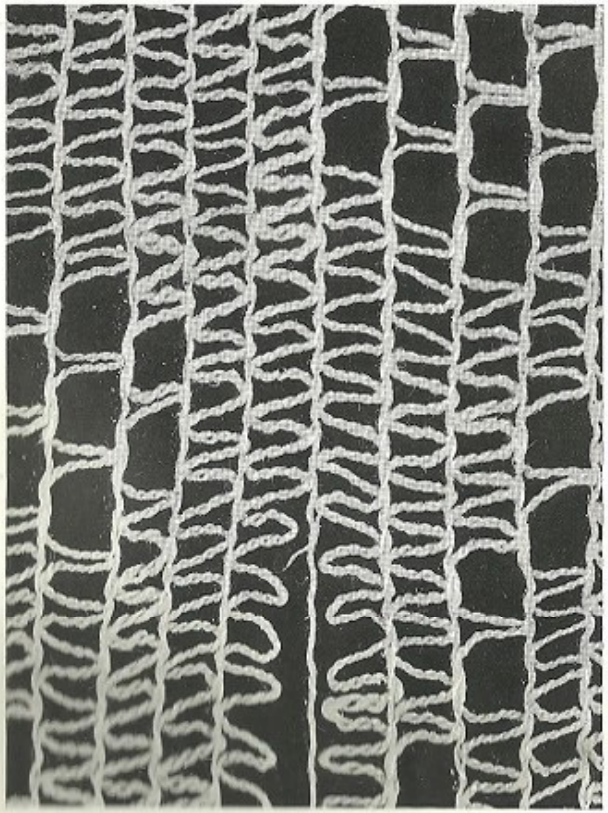


Fig. 13. — Magnified photograph of lace fabric, showing it is made by twisting together warp yarns.

(Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

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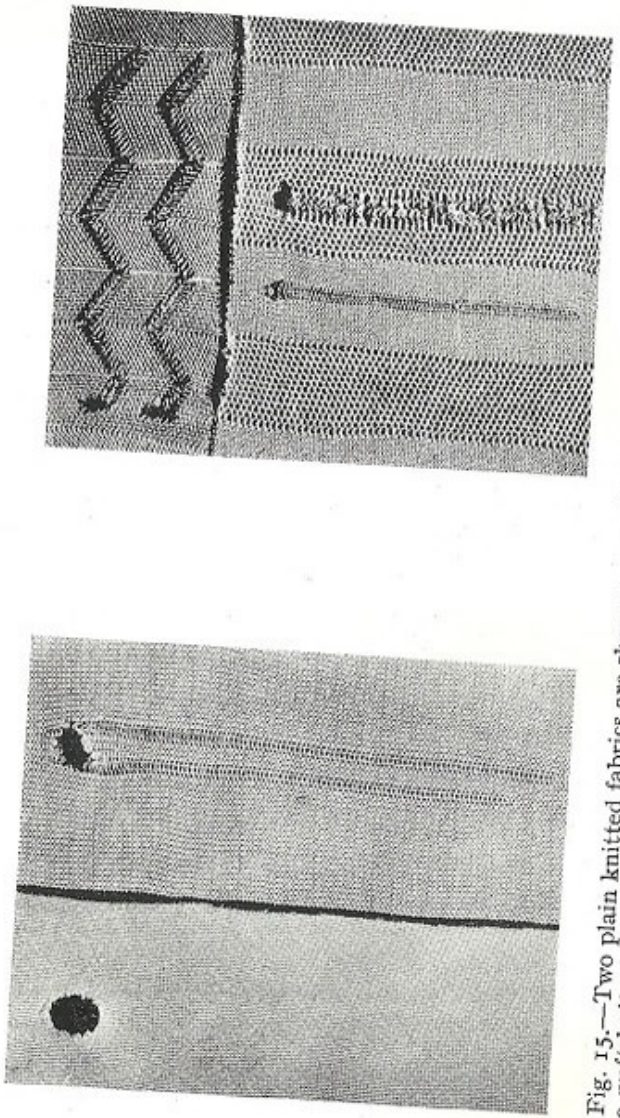


Fig. 15.—Two plain knitted fabrics are shown; one, the ladder-proof warp-knit and the other a weft-knit which ladders. Two ribbed fabrics show the warp-knit, which is not ladder-proof, and an ordinary weft-knit fabric.

[*To face page* 19.

rougher yarns which will not slide easily, such as in woollen hosiery, laddering does not occur so readily.

In warp-knitted fabrics two threads are used, forming two knitted fabrics intermeshed one with the other. The knitting, however, is not of the ordinary type where the thread runs at right angles to the length of the fabric and right across the width. In the usual types of warp-knit fabrics the threads run diagonally to the fabric, either right across the length or zigzag to and fro. This makes the fabric less elastic and breakage of a thread does not usually produce a ladder. The cheap type of warp-knit fabric forms ladders, but they are zigzag across the material. In better types of warp-knit breakage of threads only produces small holes which will not ladder.

Ordinary knit fabrics stretch very easily in either direction, but warp-knit fabrics stretch to a much smaller extent. This distinguishes the two types. To test whether warp-knit fabric is the ladder proof type, cut a small hole and then pull the fabric from one direction, and then from another. The cheap type will give the zigzag laddering; the good types refuse to ladder. In Fig. 15 the three types are shewn after a small hole has been cut and the fabric has been pulled.

Weft-knit fabrics may be knitted on circular frames or on flat frames. In the case of shaped articles, such as hose or underwear, the distinction is important. In the circular frame machine there is a constant number of needles and the fabric cannot be shaped by the dropping of the needles. In the flat frame machine, the fabric can be shaped, and the shaped item is subsequently joined by a seam. The backs of four types of hose are shown in Fig. 16.

In one case no seam is present. In another a seam is present, but if any row of needle loops is followed down it will be seen all run parallel to the seam. Whereas in the third hose a number of needle rows end where needles have been dropped a short distance away from the seam. The three types are often respectively termed seamless, mock-fashioned, and fashioned.

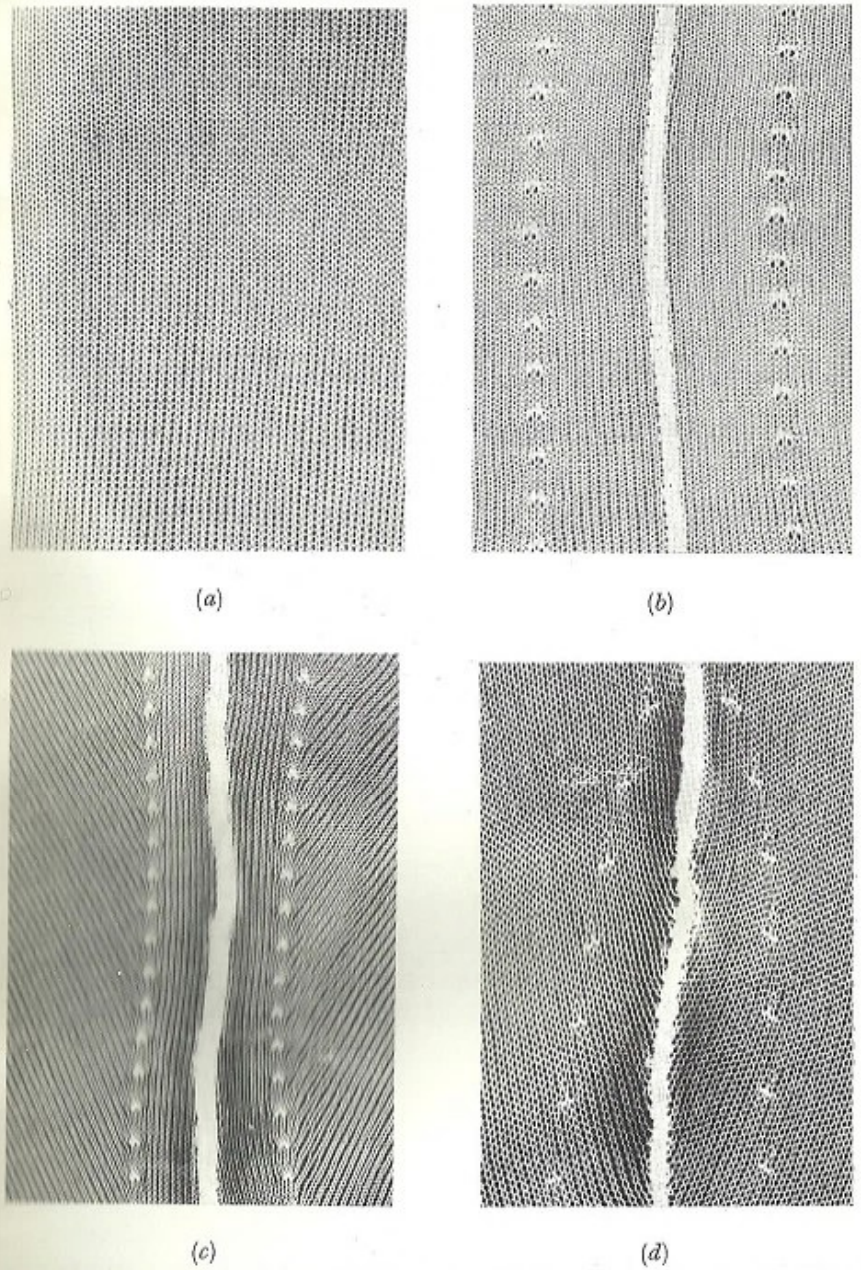
In Fig. 16 (*d*) is shewn a portion of shaped seamless hose of a type which is not common. The inwards curve to the ankle has been secured by carving out a piece of fabric on the seaming machine and then over-stitching.

When round-frame products such as hose are bought, they will be shaped, but this shaping is secured by boarding out. After washing the hose loses its shape and becomes one long cylinder. Fashioned hose, however, have a natural shape which they retain after washing. In hose which are not fashioned the ankle portions become loose and ill-fitting after washing, and in children's socks there is no natural shaping to the leg, and so the socks easily fall down on to the ankle.

There is a very considerable difference in manufacturing cost between round-frame products and fashioned products. With the advent of mock-fashioning it is important to distinguish the types. The following down of needle-rows to ascertain whether any are dropped is an infallible method.

Section 4

Finishing Processes for Fabrics.—The manufacturing operations from fibre to fabric comprise at least three stages, usually carried out in different



(*a*) (*b*) (*c*) (*d*)

Fig. 16.—The backs of hose. (*a*) seamless; (*b*) mock-fashioned; (*c*) fashioned; (*d*) a special type shaped by cutting and overstitching.

[*To face page* 20.

of sodium phosphate. Each fibre receives a transparent plating of tin phosphate. By continued treatments it is possible to make one pound of silk into two, three, or even four pounds of weighted silk. The merits or demerits of silk weighting of this type will be discussed later. But weighting is very much cheaper than silk, so if two silk fabrics are similar and have equal weight per square yard, then the unweighted one is of far greater value.

Some finishes are permanent and others are not. This is an important consideration. Dressing on cotton goods is removed in washing, while mineral weighting on silk is unaffected by washing. Linens are often given a finish known as " beetling." This is obtained by dropping wooden weights continuously on the fabric for a long time and crushing the yarns flat, and so filling in the spaces between the threads. A similar treatment can be given to cotton goods. Beetled linen has a permanent finish ; beetled cotton goods may look like linen before they are washed, but the effect then disappears. The lustre and crunch of silk is increased by dipping the silk into dilute acid (sulphuric, tartaric, or acetic for example) and then drying, a process known as " scrooping " ; this extra lustre disappears to a great extent on washing. It can be restored if the goods after washing and rinsing are immersed in weak acid, say a half-teaspoonful of acetic acid to a quart of water, and then dried.

With mercerised cotton or with rayon scrooping is secured by passing the fabric through a soap bath and then through an acid bath.

A special finish on cotton is that known as mercerisation. This may be done in the yarn or in the fabric. The material is immersed in a strong solution

Magnification × 100.

Magnification × 260.

Normal cotton fibres.

Magnification × 100.

Magnification × 260.

Mercerised cotton fibres.

Fig. 17.—Cotton fibres in length and cross section before and after mercerising.

(*Courtesy of the British Cotton Industry Research Association.*)

[*To face page* 23.

of caustic soda. This causes a very considerable swelling of the fibres. Originally the cotton fibre is broad and thin and like a twisted ribbon; after mercerising it swells to an even cylindrical shape. This is shown in Fig. 17. After a suitable period of treatment the caustic soda is washed out. During mercerisation a very considerable shrinkage occurs, but to secure the lustrous effect it is necessary to counteract this, and so during the process the yarn or cloth is kept under tension. The mercerising process is also sometimes used on linens, and it enhances the lustre of the fabric.

A somewhat analogous treatment used on cottons is a parchmentising or "linenising" process. If cotton is treated with a strong solution of sulphuric acid, the fibres first swell and become cylindrical, and they are later decomposed. By regulated treatment the swelling only is secured, and a fabric is obtained which has yarns which are very smooth and compact owing to the fibres having swollen. Moreover, these smooth, compact yarns are less affected by rubbing wear and less easily soiled, for dirt cannot penetrate.

In normal use, fabrics made from cotton which has been swollen can be expected to give longer wear. But it is to be noted that these treatments make the fibres less resistant to damage by chemicals.[1] In consequence, bleaching treatments at laundries may weaken them where ordinary cotton would be practically unaffected.

Another treatment of cotton or linen fabrics is "firing" or "gassing." This is a process involving the rapid passage of the fabric over a red-hot copper plate or over gas jets, so that the loose surface fibres

[1] Birtwell, Clibbens, Geake and Ridge. *Journal of the Textile Institute*, 1930. Vol. 21, p. T 85.

standing out on the cloth are burned off without damage to the material. This gives a smoother and cleaner fabric. This process is carried out prior to any bleaching or dyeing operation.

Most fabrics require to be bleached before they are merchantable.

With cotton, linen and cellulose rayon this is done by the use of hypochlorite of soda or hypochlorite of lime (commonly called chloride of lime). The cloth is first given a boil under pressure in weak alkali or weak caustic soda to remove impurities. The impurities removed from flax fibre in bleaching represent a considerable weight, for a linen cloth after full bleaching loses 20% to 25% of its original weight.

A small part of the bleaching of linen is secured by " grassing," that is laying the fabric out in fields, when some bleaching is secured by the combined action of the sunlight and the dew. The efficacy of " grassing " depends greatly upon the nature of the alkaline and weak acid treatments given to the fabric before and after the grassing operation. This is shown by the fact that before the discovery of the use of hypochlorite for bleaching, the use of proper alkaline and acid treatments halved the time required for grass-bleaching. In modern practice, grassing is only used to give a surface action which enhances the beauty of the linen. Complete bleaching is not secured by this means, and if it were attempted the cloth would probably be appreciably tendered, for the grassing bleach is a slow process and there is simultaneously tendering by sunlight and by micro-organisms acting on the linen. In so-called " sun-bleached " linens at least 90% of the bleaching is usually due to chemicals.

Special care is necessary in the bleaching processes for cotton, linen and cellulose rayon, as excess treatment weakens the fibres very considerably, and also causes the fabrics to become yellowish during storage.

With silk and wool the bleaching is usually done by exposure of the fabrics to sulphur dioxide (the fumes of burned sulphur). This bleaching differs from hypochlorite bleaching, which destroys colour by the addition of oxygen, for sulphur dioxide bleaches by the removal of oxygen. In consequence the colouring matters on silk and wool may later absorb oxygen from the air, and again become yellowish. Another feature of bleached wool is its unpleasant smell. This is mainly due to sulphur dioxide, and it is very noticeable with blankets, or when white woollens are stored in an enclosed space.

It is possible to secure a permanent bleach on silks or woollens. This, however, requires the use of hydrogen peroxide, or of chemicals which can generate hydrogen peroxide. Such processes are more expensive than the sulphur dioxide bleach. Hypochlorite decomposes and destroys silk or wool ; it cannot be used for bleaching, and it is only used on wool under specially controlled conditions when processing wool to make it unshrinkable.

Woollen fabrics after manufacture can be given a chemical treatment which will either decrease the liability to shrinkage, or if carried far enough will make the fabric unshrinkable. This is secured by a treatment with hypochlorite solution (bleaching powder) and acid. The process is not an expensive one, but when woollens are claimed to be unshrinkable it is important they should be so. This matter will be more fully discussed in a later section.

A serious problem in certain cases is that of the inflammability of fabrics, such as cotton, linen and rayon. Various fire-proofing processes exist. A very effective and simple one is to take five parts of boracic acid, six parts of borax and dissolve in one hundred parts of water. If fabrics are immersed in this, and then squeezed out until they are doubled in weight by the solution absorbed, and then dried, they will be found to be fire-proof. The testing for degree of fire-proofing is the simple one of applying the flame of a match, or a taper; the fabric should only char, and when the flame is removed any glowing carbon should only glow for a few seconds. The fire-proofing process mentioned can be applied to all goods, plain or coloured, but the proofing is removed by washing or soaking in water. Other processes using metallic salts such as tin or aluminium are claimed to be permanent; but, unfortunately, severe washing usually removes the fire-proofing to a considerable extent.

Finally, rain-proofing processes such as are applied to coatings and dress fabrics require brief consideration. The principle of these processes is to render the cloth resistant to wetting, so that drops of water will run off. The degree of proofing can, therefore, be measured by the water absorbing powers of the fabric, a quality termed its "imbibition." A portion of cloth is weighed, immersed in cold water for ten minutes, and then taken out and allowed to drain for fifteen minutes. It is then reweighed. The increase in weight, expressed as a percentage of the original weight, is the "imbibition." Unproofed fabrics will have imbibitions of about 150% to 250%, according to their nature. Proofed cloths will have imbibitions of from 25% to 100%.

The imbibition gives a measure of the "proofing" applied, but the actual resistance to rain penetration depends also on the closeness of the weave of the fabric. This resistance is measured by the drop test. As used by the United States War Department this means that drops of water fall from a height of five feet at the rate of twenty per minute on to a piece of cloth laid flat on a glass plate supported at an angle of forty-five degrees. Between the cloth and the glass is a sheet of very fine white blotting-paper, and so soon as water penetrates a blot is seen reflected in a horizontal mirror placed underneath. Some highly proofed cloths may permit penetration at the first drop; they are useless in a rainstorm. Satisfactory rain-proofs will resist the impact of six or seven drops before penetration occurs, and some fabrics will resist sixty or seventy drops.

Other measurements for resistance to rain penetration are based either on the rate of flow of water through the fabric under a certain pressure, or preferably on the pressure of water necessary to give the first penetration of water. A rain-proof fabric should withstand a pressure of six inches of water before penetration occurs. For this reason, any demonstration based on water flowing over a fabric, or on a pool of water on the fabric, may be of small value. The value of the pool demonstration will depend on the depth of water in the pool.

An ingenious method for proofing silk hose against mud splashes was secured by dipping the hose in a 5% solution of paraffin wax in petrol. This proofing of fabrics with wax is very effective. The author reproofed a leaky hood of a motor car by pouring six ounces of melted paraffin wax into a gallon of petrol

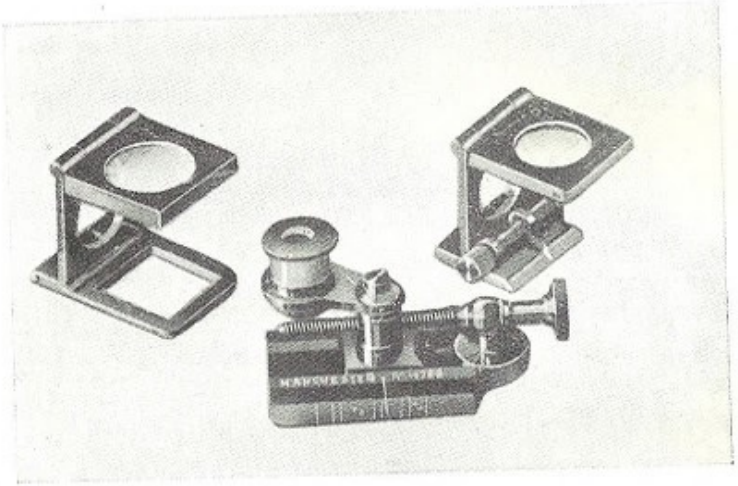


Fig. 18.—Thread counting glasses.

(Courtesy of J. Nesbitt, Ltd., Manchester.)

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The fineness of construction is of great importance as affecting cost; for instance in a woven cloth a loom working at a definite speed will produce twice as much cloth with say 50 weft threads per inch as with 100 weft threads per inch. Weft threads per inch are often referred to as picks per inch and the warp threads per inch as the ends per inch; the closeness of weave is often given as ends and picks or the term reed and pick of a cloth may be used. Various thread-counting glasses are illustrated in Fig. 18. If a cloth be made with a certain total of ends and picks it is cheaper to increase the number of ends, so in decreasing the weaving cost of any cloth the decrease will be shown in less picks per inch. In knit fabrics the loops (or needles) per inch can be counted, and also the courses per inch (see Fig. 14); in the comparison of several knit fabrics a useful figure is the product of needles per inch and courses per inch. Sometimes the needles per inch is expressed as the gauge, and in hose this means the number of needles in one and a half inches of the knitting machine.

The nature of the yarn is important, as worsted or woollen, nett or spun, folded or single; in each case the more expensive yarn has been mentioned first.

CHAPTER III

TEXTILES IN WEAR AND WASH

Section 1

General Remarks.—Any textile product has three characteristics. These are Appeal, by which is meant appearance, handle, colour, fashion and the like, Utility by which is meant capacity for giving the expected service and satisfaction in use, and Cost. Actual value in the product can only be determined by considering all three of these characteristics.

The Appeal and Cost of the fabrics offered by a distributing house are matters which call less for exact knowledge than for artistic judgment and business acumen in its buyers. But they are also matters which the customer can judge for herself and, if she is mistaken, she will probably lay the blame on herself. This is not so with Utility. In this matter, the customer cannot usually form a reliable judgment; she must leave this responsibility to the retail house, and so the Utility is the province either of the scientist or of the buyer applying scientific knowledge.

The exact Utility qualities required in a fabric must of course depend upon the conditions of usage. For example the fact that a fabric may be made into a fashion garment which will only receive a short period of wear, and then be discarded, does not suffice as an excuse if the fabric tears, or the colour fades, in that period. On the other hand there is no need to limit

the choice among colours, and to add to cost by putting fadeless-to-light dyeings on fabrics only intended for evening wear. Sufficient Utility is required for the fabric to last a reasonable length of time in its normal use, plus a reasonable factor of safety.

Space has been devoted to this matter because some people argue that as fabrics often have a short fashion life, the Utility is not important; other people will complain if the fabric is not practically everlasting. These are extremes, the one wasteful and the other impossible.

As it will require much space to consider the colour question, this will form the next chapter of this book. In this chapter only the properties of the fabric itself will be considered.

Section 2

Tensile Strength.—There are three distinct types of breakage of cloth. The first is when stresses occur as a pull along either the warp or the weft; here over the width of the strip each thread takes its share of the strain until rupture occurs. This gives an exact measurement of strength. Then there is the tear. Here the force is applied to one thread or at most it may be shared slightly by one or two threads below. Tearing is not a good gauge of strength, as the force required will depend on the angle of the pull and the rate of tearing.

Finally, there is the bursting of cloth produced by an outward pressure spread over an area of fabric. If a bursting stress is applied to a cloth and one set of threads can stretch, while the other set is only slightly elastic, the effect is clear; one set of threads stretches, so reducing the stress, and

the other set cannot stretch, and takes all the stress, and finally bursts. Thus the figures for bursting strength of a fabric should be regarded with some suspicion, for a cloth with a very weak but elastic weft, and a strong inelastic warp, will give a high bursting strength, but owing to the weft weakness it may not be a desirable fabric.

With knit fabrics, however, the bursting strength test is the most useful test. With weft-knit fabrics it is difficult to get any significant tensile strength except by testing the strength of the yarn. With warp-knit fabrics tensile strength tests can be obtained, but bursting tests are the most useful in comparisons.

The tensile strength of fabrics is appreciably affected by the moisture content. Cotton and linen fabrics are stronger when wet, but other fabrics are weaker. This is shown in Table[1] No. 2, which gives the wet strength of single fibres expressed as a percentage of the dry strength.

TABLE NO. 2

Relation of wet strength to dry strength of textile fibres.

FIBRE.	Wet strength of single fibres expressed as percentage of dry strength.
Cotton	110–120
Wool	85–90
Natural silk	75–85
Fine filament cuprammonium rayon	50–60
Viscose rayon	45–55
Cellulose nitrate rayon	30–40
Cellulose acetate rayon (English)	65–70

[1] Obermiller, and Goertz, *Melliands Textilberichte*, 1926. Vol. 7, p. 163.

It should be noted, however, that when cotton and linen are deteriorated (as by over-bleaching, severe wear or other causes) the wet strength is less than the air-dry strength.

In the case of spun yarns the wet strength of the yarn may be affected to a greater extent than is the strength of the single fibres, because fibre slippage in the yarn may more easily occur wet than dry, and this, of course, will apply more to loosely twisted yarns than to tightly twisted yarns. In consequence some woollens and spun silks are very considerably weaker when wet.

For tensile strength tests it is therefore desirable that comparative tests shall be performed with the fabrics containing a definite amount of moisture. But for practical purposes two tests will suffice; one with the ordinary air-dry fabric and the other with wet fabric.

In reports from a laboratory the breaking strength may be given for say a four inch strip grabbed by a machine called a dynamometer. The grab test leaves loose fabric at each side and so prevents any error due to irregularly cut edges. The samples have to be fixed in carefully to get a pull that is straight along the warp or the weft, or only a tearing effect would be produced.

Now when tensile strengths are given for several samples there is one very important point for consideration. Experience has shown that fabrics which have torn in normal wear or wash have a tensile strength of about 40 to 50 lbs. (or less) per four inch grab test, say a breakdown strength of 45 lbs. If two samples of similar cloth have strengths of 75 lbs. and 90 lbs. the strengths appear fairly close; but on

subtracting the breakdown strength the relations are 30 lbs. and 45 lbs. and so one will probably last 50% longer than the other under normal conditions of wear or wash.

The greater part of the stresses to which a fabric is subjected during its useful life are longitudinal, that is in the direction of the warp threads. If a fabric must be weakened in either warp or weft to get some special effect, it is therefore desirable that the weakness be in the weft. In considering a weak fabric, weakness in the warp is the more serious.

The actual strength of a fabric depends on a number of factors; the quality of the fibre, the type of the yarn, the closeness of the weave, and the weight of the material. As all these factors affect cost it may be taken that the cheaper the fabric for its type the greater the risk of low strength.

The comparative strengths of the various yarns are of interest and are given in Table No. 3.[1]

TABLE NO. 3

Comparative strengths of various types of yarn.

Type of yarn. Each yarn equivalent to 30's single worsted.	Turns per inch.	Breaking strain in ounces. 1 inch test.	27 inch test.
Silk	4	45.0	40.0
Ramie	12	34.5	24.5
Linen	15	29.5	18.0
American cotton	14	17.0	13.5
Viscose rayon	2	11.0	11.0
Lustre worsted	9	9.0	5.0
Botany worsted	9	7.5	3.5

The relative strength of the rayon was correct in

[1] *Barker Journal of Society of Dyers and Colourists*, 1905, p. 36.

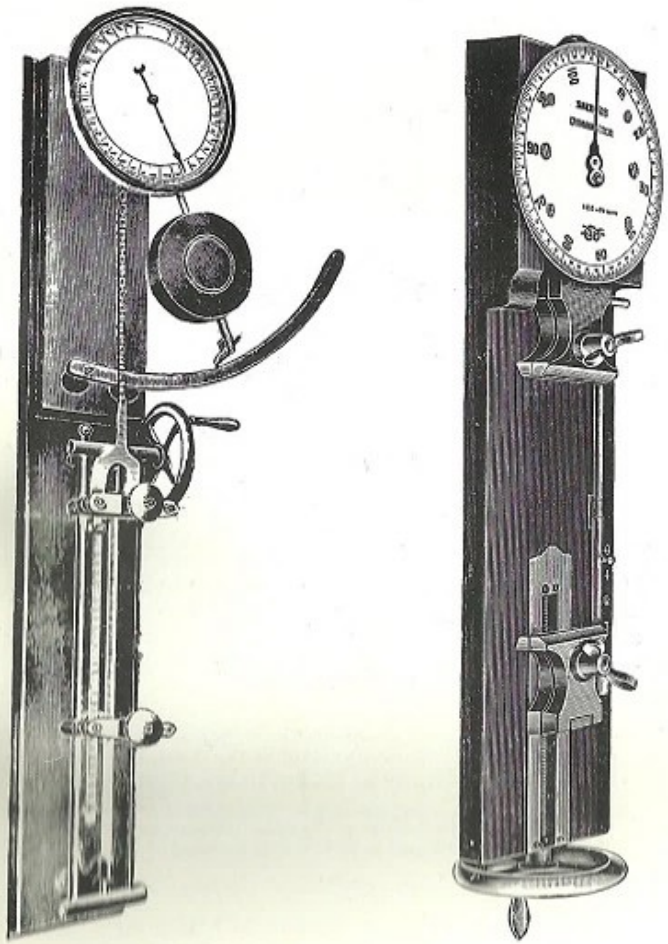

Fig. 19.—Two types of apparatus for testing the breaking strength of fabrics. One is operated by the lifting of a heavy weight (J. Nesbitt, Ltd., Manchester), and the other by the pull-on springs (Geo. Salter & Co., London).

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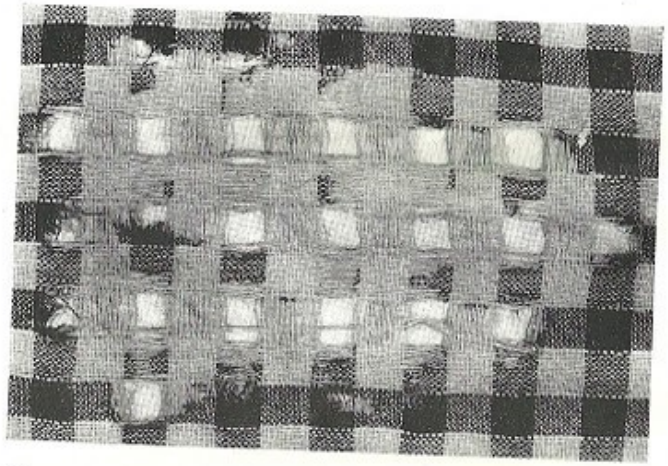

Fig. 20.—The black threads in this fabric were dyed with a sulphur black dyestuff and became tendered and rubbed away as shown in the photograph.

(Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

To face page 35.

1905 when the measurements were made. Since then rayons have been improved. It will be noted that the strengths of the nett yarns (silk and rayon) are not much affected by length, but the spun yarns are considerably weakened if long lengths are tested. For comparison in cloth, the one inch test is most true, but the twenty-seven inch strength is the important measure as regards strength for weaving in the loom.

The comparative strengths of silk and present day rayons are given below with silk taken as 100. Lilienfeld rayon is a viscose rayon made by a special process and it is as strong as silk, and it can be made in filaments as fine as real silk. Fabrics made from this rayon are now (1930) being introduced. Silk . . . 100, ordinary cellulose rayon . . . 40, cellulose acetate rayon . . . 26, Lilienfeld rayon . . . 100.

One common cause of weakness in fabrics of cotton, linen, or rayon, is tendering produced by carelessness, or by some accident, in bleaching. For instance, a sample of winceyette retailed at 8½d. per yard was bought for comparison tests. In weight and sett of weave (warp/weft threads per inch) it appeared a very good fabric at the price. Its tensile strength should have been about equal for warp and weft and about 120 lbs. Test showed warp . . . 61 lbs., weft . . . 56 lbs., and also that the fabric was seriously over-bleached. This low strength is bad, for it is near to breakdown strength. But after an ordinary boiling wash the strength of the fabric was only warp . . . 38 lbs., weft . . . 31 lbs., and now it would certainly not resist the normal strains of wear and wash without breakdown. This material was worthless; it would not even justify the time and labour of making up.

The shop that sold this material sold trouble for itself and for its customers.

This is an important point that should be especially noted. When a cellulose fabric has been tendered by overbleaching, it will lose further strength in the first hot or boiling wash.[1] Part of the material actually dissolves away.

Tendering may also occur in the final finishing operation. For instance, if a glazed finish is required on cottons they must be calendered at a temperature of 280° to 320° F. But if the cloth contains Epsom salts or an excessive amount of zinc or magnesium chlorides, it is very severely tendered at this temperature, as it cannot safely be calendered at over 180° to 200° F.[2]

Another type of tendering which may occur in cellulose fabrics (cotton, linen, rayon) is due to a class of dyestuffs known as the sulphur dyes. These give very fast colours, but on occasion the dyes become partly decomposed, producing sulphuric acid, which rots the fabric. Sulphur-dyed fabrics have been exported, which, when they arrived at their destination, practically fell to powder. This class of defect does not appear to be common nowadays. In six years' experience in testing for the retail trade, the author has only met one fabric tendered in this way. The most commonly used sulphur dyestuff is a black colour. An illustration of this trouble is shown in Fig. 20.

Cotton and wool goods that are raised or fleeced to get a desired finish may be weakened seriously by over-raising. In cashmere and camel hair cloths

[1] Clibbens and Ridge. *Journal of the Textile Institute*, 1928. Vol. 19, p. T 389.

[2] Pickstone. *Textile Mercury*, 1924. Vol. 70, p. 4.

the weakness may lead to the cloths stretching both in width and length when they become wet.

In the previous chapter of this book it was mentioned that cellulose rayon loses much of its strength when wet. With average present day rayons the material retains about 45% to 50% of its dry[1] strength when it is wetted; a new type of ordinary rayon (Lilienfeld rayon) has a strength retention of about 70% to 75%. In 1904 the rayons then available had a retention of about 15%, and so 85% of the strength of the material was lost during the washing. In all cases rayon regains its original strength when it is dried.

The strength of rayon fabrics therefore involves two factors, the dry strength and the wet strength. Dry strength alone is not enough guide, for the author has examined cellulose rayon fabrics with wet strength retention as low as 20% and as high as 60%. Experience shows that most accidental tears in the wash are with rayons whose retention is 40% or lower. An example was a rayon and cotton net curtain which had torn very badly after one careful wash. The rayon had a retention of 20%, and this left the yarns too weak to withstand the strains of lifting the wet fabric.

Rayon fabrics require careful selection before use for umbrella covers. A rayon umbrella cover fabric examined had a weft strength of 58 lbs. (for a 4 inch grab test); this is low, but its retention was only 28%, so when wet its strength was only 16 lbs. It was advised that this material would probably tear during use in the rain; and the shop that bought the material which was rejected for this reason had a

[1] Unless specifically stated, the term "dry" is used in this book as meaning "air-dry" and not completely freed from moisture.

very large percentage of complaints with this umbrella cover. A cover passed as satisfactory had a rayon weft strength of 150 lbs. and a retention of 62% ; say a wet strength nearly six times that of the previous cover.

Weighted silk is a fabric that may be low in strength owing to perishing. This perishing may be due to the effects of sunlight or it may be due to defective processing. Lack of care during the weighting may cause tendering or such fabrics may tender during storage. Silks that are properly and not excessively weighted, however, do not perish if stored normally and away from light. A number of samples of tendered weighted silk (crêpes de chine) were tested and the average weft strength (for a 4 inch grab test) was 30 lbs., while that of normal fabrics of this type would be 60–65 lbs. Such perished fabrics are often jobbed off and then made into garments. These garments are, of course, very quickly damaged in ordinary wear.

In knit fabrics it is equally necessary to test the strength. Consider, for instance, some rayon milanese which was tested. It was of low strength while dry, but had almost no strength at all when wetted. The main cause of its loss of strength was overbleaching. With ordinary pure silk hose a strong, straight pull has no effect. But with one lot of weak pure silk hose the effect of a simple pull was disastrous ; in place of nett yarns the hose was knitted from spun silk, and owing to the low twist these yarns were far too weak.

Exact work for the scientific comparison of samples, or for the buying of the best fabrics, can only be done with special apparatus. But by hand tests three grades of strength can be distinguished. With the palms facing the body, place the middle segments of the index fingers together. Have the fabric resting across the platform so made, and then clamp down the cloth with the thumbs against the index fingers. This grip is shown in Fig. 21. Now with the elbows raised from the side (to prevent any leverage) give a slow, straight pull. Note that this pull must be straight along either the warp or the weft, or a tear will occur and not a rupture, and also the pull must be in the cloth (not including a cut edge). If a fabric ruptures under these conditions it is Grade 3 in strength. Supposing it does not break, then take the

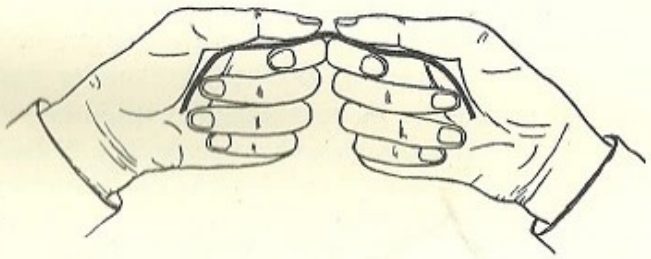

Fig. 21.—The grip used in the hand testing of fabrics for tensile strength.

same grip with the cloth tight across the finger platform, and have the bottom segments of the little fingers in contact to form a fulcrum, and then bend the wrists, seeking to turn the palms upwards. This gives a greater strain on the fabric, and if it ruptures the strength is Grade 2. Cloth which cannot be ruptured by this test is Grade 1.

A fabric that has a hand-test strength of Grade 3 is likely to tear in wear. The next thing to do is to procure other samples of the same fabric, but from different sources and to hand-test these. In very fine and light-weight fabrics strength inevitably is decreased, but the comparative strength tests will

indicate whether the fabric is unusually weak. Of course, the ease of rupture with the test gives a further guide. With rayon goods the strength wet must also be tested. With cotton goods the dressing (which contains starchy adhesive matter) may give rise to an untrue strength if the fabric is tested dry; so tests should be made with dry fabric and with wet fabric, for when wet dressing cannot add appreciably to the strength of a fabric.

In concluding this section it may be noted that the tensile strength of a fabric does not give a measure of the work required to break a fabric, or its capacity to resist a definite shock. For estimation of this characteristic the stretch of the fibre under various stresses is required. A very useful method of testing which is slowly coming into use is the "ballistic test,"[1] where a falling weight breaks the yarn or fabric, and the energy absorbed is measured. This test, however, can only be performed with special apparatus, and so it is not considered in detail in this book. It should be noted, however, that if two fabrics have equal breaking strengths, then the one which stretches the most before breaking will be the most resistant to shocks in wear.

Section 3

Frictional Wear.—In many cases the usage of a fabric involves its slow weakening owing to the rubbing away of the material by friction against other substances, or against itself.

With faced fabrics the wear first shows itself by the removal of the nap, and in the examination and comparison of this type of fabric tests may be made by

[1] Lester. *Textile Mercury*, 1909. Vol. 40, pp. 313, 334 and 356.

rubbing cloth on cloth under a definite pressure and noting the effects produced by the number of rubs. In the author's laboratory the weight is one kilogram over an area of 20 sq. cms. and the fabric receives up to 4,000 rubs. These tests are applied principally to suitings and overcoatings.

This rubbing wear test on faced fabrics is sometimes very important. The removal of the nap may so affect the appearance of the cloth that worn portions are very obvious, though with good quality cloths, evenly dyed, wear does not usually show a short distance away. In cheap wool and cotton union cloths (dress fabrics, suitings, and particularly flannels) the cotton threads are sometimes only slightly coloured, and so when the wool surface nap is worn away the wear shows very distinctly. In examining such cloths it is a simple matter to remove threads and to compare their shades of colour; and if they are markedly different, then it is sure that worn surfaces of the cloth will be very evident.

Apparatus can also be procured to make measurements of the wear resistance of any other fabric such as shirtings, table linen, and bed linen.

The more smooth a fibre the less the friction it will offer to rubbing wear. In consequence rayon fabrics have proved to be very suitable for coat and sleeve linings, and in upholstery fabrics such as damasks the smooth rayon patterns prove very resistant to wear. The usual alpaca fabric is smooth and so resistant to frictional wear. And the linenising of cotton sheeting with sulphuric acid (see page 23) makes the sheets wear much longer because the fabric is more smooth than ordinary cotton. One fabric especially exposed to severe rubbing wear is pocket

lining, particularly that used in trouser-pockets. One firm has made a special study of such fabrics and has produced a pocketing that has four or five times the wear resistance of the average pocketing.

The initial strength of the fabric is, of course, an important factor as well as the rate of loss of strength of the fabric in determining how long wear can continue before breakdown strength is reached. For instance, under equivalent conditions of simple rubbing wear, linen will last very much longer than cotton because it starts with practically double the original strength.

One factor affecting resistance to frictional damage (which occurs in wash as well as in wear) is the state of the fibre.

The cotton fibre is in appearance a thick ribbon with frequent twists in it. The outer layer of this ribbon is a form of cellulose resistant to damage, but once this layer is damaged by heat, overbleaching, acid, or micro-organisms the cotton is much less resistant to frictional wear.

The wool fibre has an outer layer of very fine scales (see Fig. 2), and the inner portion consists of a number of very small fibres forming a large cylinder which sometimes has a central channel. In wear, or wash, or recovery from old fabrics, or by the action of chemicals such as are used to make wool unshrinkable, or by the action of micro-organisms, the wool may have the scales removed and the central portion may commence to break down into its constituent fibrils. The damaged state of the fibres of shoddy (wool recovered from rags, etc.) is shown in Fig. 22 and the fibrils can be seen as brush-ends on some fibres.

Any stage in this break-down means that the wool is less resistant to frictional wear.

With cellulose rayon the filaments swell and soften when they are wetted; and, in consequence, wet rayon is much more readily damaged by frictional wear than dry rayon. On one occasion a complaint was investigated which concerned the poor wear of a stockinette skirt. This consisted of wool and rayon yarns, and in patches on the garment the rayon had disappeared, and only wool remained. Test showed that if this fabric was rubbed while wet, the rayon part of the yarn easily broke up and rubbed away.

In another case a rayon stockinette garment was returned with a number of small tears or cuts in the fabric. Investigation showed that if the fabric was ironed while damp with a cool iron and the toe of the iron pressed suddenly on the fabric, similar small tears or cuts were produced. With a hot iron this damage could not be produced, for the rapid drying of the rayon restored it to normal strength, and it could then resist such a treatment.

Silk is also more liable to frictional damage while it is wet. For instance, whitish patches sometimes appear on Jap silk mackintoshes; these are usually where the belt has rubbed on the fabric, and where the arms have rubbed during walking. Microscopic examination shows these light patches to be due to frayed up portions of the silk filaments. Similar patches can be produced by rubbing one piece of wet silk on another piece, but they are not produced using dry silk. Cases have also occurred of the fraying of silk hose by Wellington type of boots; here again the damage only occurs easily when the silk is wet. This chafing of silk may occur in dyeing or finishing if care

is not taken. The effect is known as "mildew" or "lousiness," and where it has occurred the fabric is rubbed with oil in benzine to lay down the frayed portion of the fibres. This treatment only covers the fault and on wear or washing the whitish patches will reappear. So, if in complaints against silk fabrics there has been no treatment in use to produce the chafing, then white marks may be due to fabric damaged in dyeing or finishing.

At this point it will be seen that the resistance to wear of a fabric will depend on (*a*) the nature of the fibre and

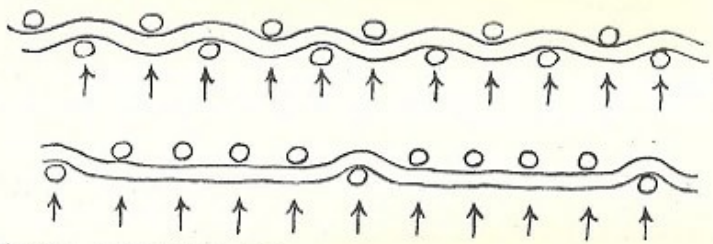

Fig. 23.—Section of plain weave and satin weave showing in plain weave the wear is distributed equally over both sets of yarns and in the satin weave the wear is very unequally divided between the two sets of yarns.

its condition, (*b*) the length of the fibre (for long fibres will not easily be dragged out of a yarn by frictional pull), (*c*) the degree of twist of the yarn (for a tightly twisted yarn can only wear the fibres on its surface while a loose yarn will let many fibres receive frictional wear), and (*d*) the smoothness of the yarns. Increased smoothness of yarns in cotton fabrics may be secured by gassing and further increased by mercerising, or by the sulphuric acid treatment already discussed (pages 22 and 23).

The nature of the weave of the fabric has a considerable influence on the wear resistance. Compare

in Fig. 23 a plain weave with a satin weave, with square sett and equal yarns in both cases. It will be seen that in the plain weave the wear is spread equally over both warp and weft, but in the satin weave the wear is very largely on one set of threads alone. This is illustrated in Fig. 24, which shows the satin weave portion of a towel worn away in laundering and use, while the plain woven portion is still strong. The yarns were of equal size and strength in both cases. For hard wear a fabric should be woven from well twisted yarns of the same size and strength for the warp and the weft, in plain weave, and with an equal number of warp and weft threads per inch. An uneven structure usually means there is uneven wear. Consider, for instance, a crêpe de chine or a marocain; here are fabrics with many loosely twisted warp threads per inch which entirely cover the fewer, thicker, heavily twisted weft threads, and so the wear is practically all on the warp threads.

A very good idea of the wearing quality of a cloth can be obtained as the result of testing its tensile strength, and from ordinary and microscopic examination. Preferably, of course, the conclusions should be checked by actual wear tests on a suitable apparatus.

One consequence of frictional wear, especially with worsted fabrics, is the production of a smooth, shiny surface. This cannot be prevented. Occasionally, however, in wool fabrics a shiny or greasy effect may be produced very rapidly, and such cases have been due to excessive oily matter in the cloth. During the spinning of wool fibre into yarns the fibres are sprayed with oil, and after the cloth is made this oil should be removed by a washing process. The use of oil that is not easily removed, or careless cleans-

ing after weaving, means a cloth defective under conditions of frictional wearbecause it develops these greasy areas. They are removed by dry-cleaning.

Section 4

Slippage.—One source of trouble with some fabrics is due to threads in the woven fabric sliding over the binding threads. This "slippage" (sometimes called "parting" or "fraying,") occurs most commonly with silk or rayon fabrics because the threads made from these fibres are so smooth.

In the body of the fabric the effect is to produce loose patches with only one set of threads visible. The slippage is caused by rubbing or by a sliding pull. Quite frequently a little gentle pulling and rubbing will restore the displaced threads to their correct position. Slippage of this type is shewn in Fig. 25.

Slippage is most common in cheap fabrics because the weave is usually less close (fewer threads per inch) and so there is less binding of the threads on to each other. One advantage of the mineral weighting of silk is that it reduces slippage somewhat in fabrics such as satins or crêpes de chine.

The more usual trouble with slippage is at the seams. If any strain is placed on a good seam slippage may occur owing to threads sliding slightly through the sewing, and this gives a semi-bare area. The effect is illustrated in Fig. 26. But if the seam has been made with only a slight turning of material, then such slippage may occur that the threads parallel to the cut edge slide right out of the fabric and the seam bursts open. The exact amount of turning that should be left in a seam must depend on the nature of the material and on its tendency to slippage. In

Fig. 24.—Weave and wear. An original and laundered towel. The coloured stripe bearing the name is a satin weave, and it has been worn away while the plain weave fabric is still intact.

Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

Fig. 25.—Thread slippage in a fabric.

(Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

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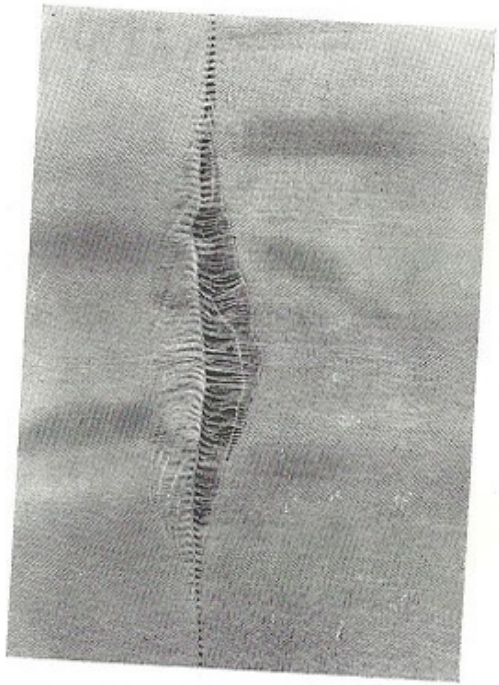

Fig. 26.
Thread slippage of a fabric at a seam.

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practically all cases a turning of at least half an inch is required. Slippage cannot be prevented in many types of fabrics and, in particular, where a bright or supple effect is required, the necessary structure means increased risk of slippage. It is, however, possible to minimise the trouble by proper design of the fabric.

Many complaints are received that are due to slippage. Heavy wear or a tight fit may cause slippage in the body of the fabric. A tight fit will cause stresses and slippage at the seams ; most frequently at the back of the arm-holes owing to insufficiently loose fit across the back, or under the arms owing to stresses when the arms are stretched upwards. In faultily made up garments insufficient turnings may lead to the seams bursting open. A little consideration of the material, make up, and fit will prevent most of these complaints. In one remarkable case examined, a velvet frock had been very carefully made. After sewing on the skirt the turnings had been carefully trimmed so that about one-eighth of an inch was left. Fortunately, only slight bursts had occurred before complaint was made. But if any strong young children had been pulling at their mother's skirt, in this case the result would have been unexpected and very disconcerting.

Simple hand tests will give some gauge of the degree of slippage of a fabric. Experience and judgment is required in the interpretation of such tests, for, given sufficient strain, practically all fabrics can be made to slip to some degree. In the laboratory slippage can be measured more exactly. A strip of cloth is folded over, sewn across about one inch from the fold, and it is now placed in a dynamometer and

a definite stress is applied to the cloth. This causes a zone of slippage on each side of the sewing, and the average width of this zone can be measured. In this manner samples of similar cloth can be tested and compared for degree of slippage.

Section 5

Other Factors in Use.—Wool or silk fabrics have a warmer feel than those of cotton, linen or rayon, as their fibres do not conduct heat as readily. But in wear the warmth of a fabric is usually only determined to a small extent by the heat conducting properties of the fibres; the principal heat insulation is due to the air spaces between the fibres.

Some tests by Scholefield[1] illustrate this. He measured the relative heat-retaining powers of various fabrics and found: linen and calico . . . 5, flannelettes of five various qualities all . . . 62, wool union flannel . . . 64, all wool flannel . . . 64. So from the point of view of retaining the bodily heat flannel is very little better than flannelette.

These facts do not justify the conclusion that cotton is as good as silk or wool for underwear which is worn next to the skin. There are other differences in properties such as moisture absorption, and moisture evaporation, which require consideration, more especially perhaps so far as summer wear is concerned. On donning, a wool or silk garment feels warmer than a cotton or rayon garment. With perspiration cotton tends to become wet and clammy owing to the fact that its capacity for holding moisture at various degrees of humidity does not correspond with that of wool.

[1] *Medical Officer*, 1929. Vol. 41, p. 228.

The alleged transparency of certain rayons to ultra-violet light has been used as a selling argument. As the beneficial effect of sunlight is well known the question of ultra-violet light transmission is important. The U.S. Bureau of Standards in 1927 reported[1] that, after eliminating the light passing through the openings of the threads, the various transmission coefficients found for various undyed cloths were:—acetate rayon . . . 11–29%, viscose rayon . . . 16–27%, cotton . . . 17–20%, silk . . . 14–18%, wool . . . 5–15%. Slight colouring by dyes or discolouration due to age greatly reduces the transmission.

The simple fact is that practically all the ultra-violet light transmission of a cloth is through the openings in the texture. To obtain the beneficial therapeutic effects of sunlight an open-weave fabric should be worn.

An important property of linen fabrics is the ease with which they absorb fluids. This absorption is due to capilliary action, and a large absorbing capacity is secured by the parallel worsted type structure of the yarn, and the roundness of the fibres. Similar yarns cannot be spun from cotton because the fibre length is too small. Linen is therefore very useful in handkerchiefs, kitchen cloths, and towels, and in the United States heavy linen fabrics are very popular as summer golf suits because they so readily absorb perspiration. Another advantage of linen arising from the nature of the fibre and the yarn is that not only does it absorb water quickly, but it also dries quickly. For kitchen cloths the freedom of linen from lint is another great advantage; this is also due

[1] *Bureau of Standards Technical News Bulletin*, 1927. No. 126, p. 4.

to long fibres, which can be spun to give a smooth yarn with the fibres firmly held.

A simple test can be of value in judging linen cloths, particularly kitchen cloths and towels. Carefully place one drop of water on the fabric when it is laid flat. At first it will lie as a small globule on the surface, but after a few seconds, or several minutes, the drop will spread out, collapse and be absorbed. Clearly the quicker the absorption the more suitable is the cloth. The most absorbent linen is that which has received a boil in caustic soda, for this removes all waxy matters which prevent the fibres becoming wetted. Ordinary linen only receives an alkali boil and not a caustic alkali boil ; it has that smooth, glossy " linen " appearance, but the caustic treated cloth that is more soft and less glossy is actually far preferable where good absorbent properties are required.

In connection with this test it is, however, necessary to state that a thorough boiling wash in good soapy water is very effective in removing any waxy matters, and so linen fabrics which are not very absorbent at first, will become so after a few good washes. But often the consumer buys articles for immediate use, or sometimes goods never get a thorough wash which will remove traces of waxy matters. The preferable linen for sale is, therefore, that which is readily absorbent and so meets these two cases.

A not infrequent complaint against mackintoshes is concerned with alleged water penetration. Frequently in new garments this is due to " condensation." In older garments it may be due to perished rubber, and of course not all new mackintoshes have good proofing. Condensation occurs if warm air saturated with moisture is cooled. For instance, if

the air is in a thin walled container and is cooled from the outside the water will deposit on the inside surface of the container. The steaming up of the windows of a crowded railway carriage is a simple illustration of this fact.

A mackintosh is not porous, and so during wear there is a layer of stagnant air retained inside. This air becomes heated by the warmth of the body, and humid owing to moisture breathed out by the skin and also from the water evaporated from the clothes (more especially if they had become slightly wet before the mackintosh was worn). In consequence it is quite obvious that on occasion water will condense on the inner surface of a mackintosh owing to the cooling of the outer surface by wind and/or rain. It is equally clear that the customer is not unreasonable in believing that water is penetrating the proofing.

To prevent or minimise condensation a mackintosh should be loose fitting, and also possess such other ventilation as is possible.

Leakage in mackintoshes occurs if the seams are not " taped." The sewing at the seams acts as many small wicks which will pass water from the outside of the mackintosh to the inside. To prevent this, strips of rubbered fabric should be stuck over the inside of the seams, a treatment known as " taping." In very cheap mackintoshes the seams are often not taped. The evils of lack of taping are worse in a mackintosh fabric with an inner cloth lining, as this absorbs and spreads the water which passes through the sewing.

The recovery of fabrics from the effects of creasing depends on the elasticity of the fibres or the yarns. Wool is very elastic and readily recovers from strains. In consequence creased wool fabrics, left to hang in

the wardrobe for a short time, again become smooth. Silk also recovers from creasing readily unless it is heavily weighted with mineral matter, when it retains its creases very persistently. Cotton and linen fabrics normally crease readily and rayon fabrics are worse, for the fibres do not recover easily from strains. If a yarn is to be made resistant to creasing, it is made with a high degree of twist. The so-called "uncrushable" rayon fabrics depend for their "uncrushability" on the use of highly twisted threads to form part of the fabric.

Section 6

Factors in Fibre Deterioration.—Wear and washing slowly tender fabrics, but other factors also operate.

The author has examined finely woven linen cloth that was made in Egypt about 7,000 years ago. It received little wear or wash, for it was used as mummy cloth. Age had taken some toll, but it still possessed reasonable strength, and it could have been washed and worn; but most of the cloth woven subsequently to it has decomposed completely.

The reason this cloth had lasted so long was that it had not been attacked by mildew or tendered by sunlight. It was stored away with disinfectant material, and had since remained dry and away from sunlight.

Mildew is a general term used to cover attack by various types of organisms. There are some micro-organisms which can live on cellulose and others which can develop on silk or wool. In Fig. 27 is a photomicrograph of very high magnification shewing mildew micro-organisms growing on and

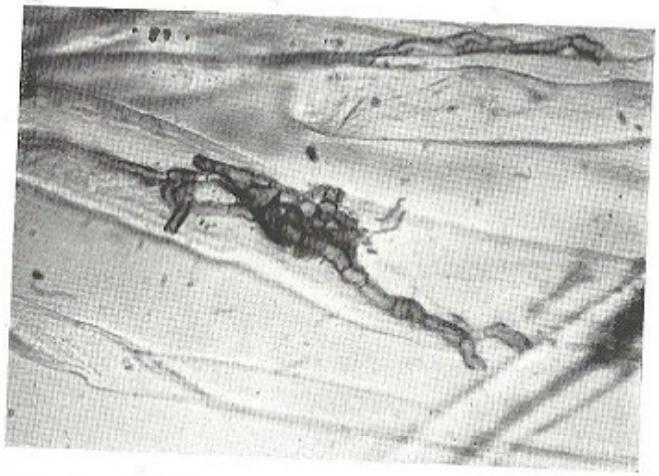

Fig. 27.—Photomicrograph of high magnification, showing mildew growing on and in cotton fibres.
(Courtesy of the British Cotton Industry Research Association.)

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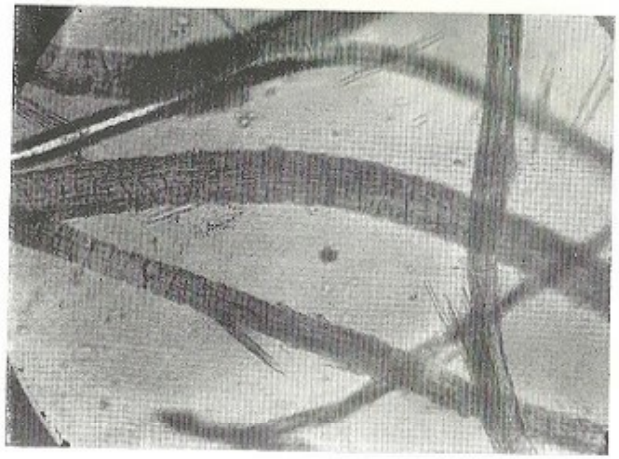


Fig. 28.—Wool fibres damaged by mildew.
(*Courtesy of the British Wool Industries Research Association.*)

[*To face page* 53.

in cotton fibres. Mildew propagates most freely in damp, warm conditions, and in so doing it often destroys the fibres. A wool bathing costume was examined which had been returned three weeks after its purchase, with the material tendered and torn. Microscopic investigation showed that the wool fibres were seriously decomposed and the report stated that it was considered this garment had been used frequently and left wet. Enquiry proved this to be true. One point of interest is that the white wool fibres were attacked, but the coloured wool fibres were apparently unaffected. Some dyes will probably act as a preservative against attacks by micro-organisms. The appearance of mildew damaged wool fibres is shown in Fig. 28.

Wool is probably the most readily affected of the common textile fibres and especially if it is left in an alkaline condition. For this reason wool should not be washed in solutions containing much soda, and, after washing, it should be rinsed very thoroughly and dried as quickly as possible. Wet wool, if alkaline (however slightly), can be damaged to a serious extent even if only left overnight in warm weather; in the acid state it is very much less susceptible. Cotton and linen are of about equal resistance to tendering by cellulose destroying bacteria. Silk may develop stains due to mildew, but it is not usually tendered.[1] Cellulose acetate is very resistant to attack by micro-organisms. For this reason it is very suitable for use as underwear in the damp tropics.

Damage by mildew is a serious problem during the whole life of textile products from fibre to worn out

[1] Heyes and Holden. *Journal of the Society of Chemical Industry*. 1926. Vol. 45, p. T 262.

fabric. It may attack the fibre during storage, causing loss of strength, or it may attack the finished cloth, in which case the colonies of mildew organisms may cause small or large spots to spread irregularly over the fabric and of various colours according to the nature of the infection. Such infected spots may not only be weakened, but the damage to the fibres may cause alteration in their dyeing properties, and so even if the tendering is not serious the uneven dyeing properties may cause considerable loss. In the retail store, or the customer's wardrobe, storage under warm and moist conditions means that very serious risks of damage are taken.

The author is informed that in shops at Durban, South Africa, it is found necessary to remove men's suitings from the fixtures every day and to brush and air them lest mildew stains develop. The climate there is warm and damp. In worn suits and frocks, staining occurs much more readily under the arms, showing that perspiration encourages mildew growth.

Some lisle hose with cashmere feet were stored in a damp basement, and they developed brown and red coloured patches on the foot portion. This is illustrated in Fig. 29. In Fig. 30 are shewn black spots on white cotton cloth due to colonies of mildew micro-organisms.

If textiles are kept normally dry mildew cannot develop. The actual seeds (called "spores") of mildew are always floating about in the air and so infection cannot be prevented. If anything capable of acting as a nutrient medium is also present development, once conditions are suitable, may be very rapid. Sometimes the dressing on fabrics may encourage the growth of mildew. Liquids such as tea or milk spilled

on fabrics would make a good medium. Warm perspiration soaked fabrics offer very suitable conditions for attack by bacteria. The author has not investigated any complaints due to this cause, but it will probably be an important factor in cases of unusually rapid deterioration of underwear or footwear.

Experiments have shewn that the presence of chromium (as in mordanted wool or khaki-dyed cotton) gives increased resistance to mildew. Men's woollen and worsted suitings are often mordanted with chromium salts, but most wool fabrics are just ordinary dyeings. So, for resistance to damp tropical conditions, woollen dresses and costumes should preferably be made of fabrics that are alizarine dyed with a chrome mordant base. Most wool bathing costumes have ordinary dyeings. They would be the better for chrome mordant dyeing, not only on account of the faster dye, but also for the increased resistance to mildew.

Fabrics definitely intended for outdoor exposure to sun and rain can be treated to produce high or even complete resistance to mildew. Such processes are useful on fabrics used for awnings, tents, garden chairs and hammocks, and for sun-blinds.

TABLE NO. 4

Tendering of cotton warp satin fabric after eleven weeks' exposure in summer.

Unbleached	18%	Bleached and mercerised	33%
Mercerised	30%	,, ,, dyed chrome green	4%
Bleached	49%	,, ,, ,, mineral khaki	6%

Sunlight alone is slowly destructive to textile fibres. The date of Table No. 4 on page 55 is extracted from a research by the Cotton Industry Research Association.[1]

Note the very considerable loss in strength of the bleached fabric, that mercerisation of bleached cloth increases its resistance to tendering, that unbleached fabric is more resistant, and finally the presence of chromium hydroxide in the cloth gives great protection against light tendering. As would be expected it was found that fine materials of loosely spun yarns were most affected since such yarns allow sunlight to affect nearly all the fibres. For resistance to sunlight the yarns should be coarse and hard twisted, and it is very advantageous to dye with mineral chrome green.

Table No. 5

Rate of tendering of various materials by sunlight.

Material.	Time of exposure to sunlight necessary to reduce strength to one-half of its initial value.
Silk	200 hours
Jute	400 ,,
Rayon (cellulose type)	900 ,,
Cotton	940 ,,
Flax	990 ,,
Hemp	1,100 ,,
Raw wool	1,200 ,,
Chrome wool	1,900 ,,

The result[2] of the exposure of materials to 100 days of strong sunlight showed the following losses in strength: silk . . . 95%, jute . . . 70%, ramie

[1] *Journal of the Textile Institute*, 1928. Vol. 19, p. T 169.
[2] Heerman and Sommers. *Leipziger Monatschrift fur Textil-industrie*, 1925. Vol. 40, pp. 161 and 207.

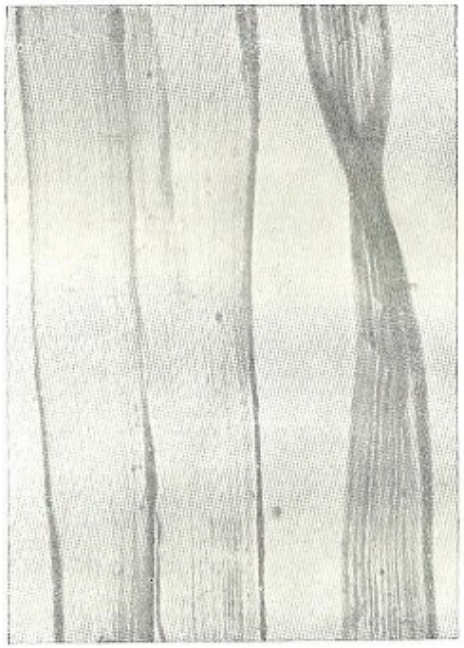


Fig. 31.—Tussah silk.

Magnification × 200.

(*From Reinthaler and Rowe's "Artificial Silk," by kind permission of the authors.*)

[*To face page* 57.

. . . 50%, linen . . . 45%, cotton . . . 40%. The data[1] in table No. 5 gives some other results of the exposure of various materials to sunlight.

The author has exposed fabrics to ultra-violet light from a quartz mercury vapour lamp, and finds the time of exposure necessary to reduce the strength to one half of the original value to be : cotton and viscose rayon . . . 21 hours, wild silk . . . 16 hours, silk (free from mineral weighting) . . . 5 hours, acetate rayon . . . $3\frac{3}{4}$ hours, weighted silk . . . $3\frac{1}{2}$ hours. The rate of loss of strength of wild silk is unusual. Instead of a loss roughly proportional to the time of exposure, there is a rapid fall in the first $2\frac{1}{2}$ hours, and then a slow fall. This is shown in the table below.

TABLE NO. 6

Rate of tendering of Shantung exposed to ultra-violet light from a quartz mercury vapour lamp.

Time of exposure.	Percentage of original strength.
$\frac{1}{2}$ hour	88
1 ,,	83
$2\frac{1}{2}$ hours	63
5 ,,	60
9 ,,	56
15 ,,	51
24 ,,	42

Probably the outside layer of the coarse fibres is rapidly tendered and then it forms a screen which has some protective effect for the inner layer (see Fig. 31 and compare with ordinary silk in Fig. 1).

[1] Sommer. *Leipziger Monatschrift fur Textilindustrie*, 1927. Vol. 42, pp. 35, 96 158, and 206.

Shantung is used for window drapery and for tropical suitings, and the above results show its value for such purposes. A length of shantung was made into window drapery and two sets were used alternately for ten years at a window with exposure to the clear sky and facing west. A portion of one (which had received the equivalent of five years' continuous exposure) had a warp strength of 93 lbs. and had lost about 48% of its original strength. It was probably good for about another five years of use.

It is not possible to give a table of the exact resistance of various fibres to sunlight tendering. The rate of tendering may be affected by many factors, such as moisture and effects of dyes and finishes, but from a consideration of the available facts, and as a rough guide, the relative rate of tendering (expressed as a percentage loss of original strength) may be expressed as: wool . . . 1, cotton, linen and cellulose rayon . . . 1.3, wild silk . . . 1.7, jute . . . 3, silk . . . 5·5, acetate rayon . . . 7·5, weighted silk . . . .12.

The value of chromium in protecting wool and cotton against mildew has already been mentioned. It will be noted that it has great value in protecting these fibres against sunlight tendering. As mildew and sunlight are two great enemies of fabrics in the tropics, chrome-dyed fabrics are clearly desirable for these conditions.

Silk (that is ordinary silk, for where wild silk is meant it is always so described), acetate rayon and weighted silk are so rapidly tendered by sunlight that they are not fitted for use as furnishing fabrics. Acetate rayon is now used for such purposes; it is a mistake. The perishing of silk was well illustrated

by a furnishing damask with a weft of pure silk and a warp of cotton and viscose rayon that was used in covering a settee which stood in a bay window with a southern aspect. After two and a half years the fabric was so tendered that it tore with a very slight strain. Tensile strength tests on unfaded portions showed (for four inch grab test): warp . . . 360 lbs., weft . . . 433 lbs., and on faded and tendered portions, warp . . . 336 lbs., weft . . . 36 lbs. In this period of exposure the cotton and rayon warp had lost less than 10% of its strength, while the silk weft had lost over 90%.

Sunlight is the cause of " perspiration rotting " of weighted silks.

For an experiment a stoker wore a piece of crêpe de chine while he cleaned out a boiler and so soaked the material with perspiration. This fabric was cut into two portions. One was tested and then hung at a window facing south in sunny summer weather. Its warp strengths were: initially . . 160 lbs., after 10 days . . . 130 lbs., after 20 days . . . 97 lbs., after 30 days . . . 63 lbs., after 35 days . . . 47 lbs., and at this stage the fabric could be regarded as rotten. The other piece was wrapped in brown paper and placed in a box, and portions were tested periodically, but even after over two years it showed no decrease in strength.

In passing, it may be noted this shows that normally weighted silk (45% to 50% of weighting) does not perish if properly prepared and properly stored away from sunlight.

Tests conducted by the United States Bureau of Standards [1] showed that 100 hours exposure to sun-

[1] *Technologic Paper of U.S.A. Bureau of Standards No.* 322, 1926.

light, tendered pure silk by about 25%, and mineral weighted silk by about 65%. Furthermore it was shown that artificial perspiration increased the rate of perishing of weighted silk by about 65%.

The constituent of perspiration that causes the accelerated sunlight tendering of weighted silk is common salt. The "acidity" of perspiration, so commonly mentioned is actually very weak, and with age perspiration becomes alkaline. As salt has this accelerating action it follows that splashes of sea-water, or even exposure to sea air, are not good for weighted silk.

The above facts will explain why silk evening frocks do not develop tears under the arms, though silk day frocks are frequently so affected. They also show why weighted silk is so unfit for tropical wear; it is tendered by sunlight about two and a half times as fast as pure silk.

The degree of weighting of the silk also affects the rate of the sunlight tendering. This is shown in the experiment tabulated [1] on page 61 giving the results of exposure of crêpes de chine on the roof of a London building to summer sunlight.

The rate of sunlight tendering is apparently very considerably reduced in silk weighted by tannic acid. This method of weighting is not much used nowadays, but with the increasing use of silks in out-door exposure it may return. Heerman by exposure of fabrics to ultra-violet light found the times of exposure to 50% loss of strength were: raw silk . . . 6 hours, degummed silk . . . 2½ hours, weighted silk . . . 1½–2 hours; but silk containing 20% of tannic acid weighting had lost only 7% of its strength after 400

[1] Private communication from W. W. Halstead, A.T.I.

hours of exposure. This protective effect of tannin is the probable explanation of the fact that in China silk coolie cloth will last fifteen years.[1] The dyeing process as described appears to employ a tannin containing vegetable extract giving a brown or black cloth according to the treatments. The protective effect of tannin is also shown by the use of a 10% solution in petroleum jelly or in alcohol to protect the skin from sunburn.

TABLE NO. 7

Rate of tendering of weighted silk on exposure to sunlight.

	Cloth. 2¼ oz. 38″ wide.	3¼ oz. 38″ wide.
Mineral weighting . .	44%	53%
Original bursting strength per sq. in.	105 lbs.	102 lbs.
Loss after 14 days' exposure to sunlight	6%	12½%
Loss after 21 days' exposure to sunlight	12%	25½%
Loss after 28 days' exposure to sunlight	31%	40½%

The defect of tannin weighted silk is, that in contact with iron, it becomes black. Iron and tannin together form the basis of black inks. This risk, however, with white or coloured silks intended for use in conditions involving sunlight exposure would probably be negligible, compared with the certainty of rapid tendering in the absence of tannin weighting. For black fabrics such as umbrella covers the use of tannin weighting would obviously be advantageous.

One special case of sunlight tendering is concerned

[1] *American Silk Journal*, 1928. Vol. 47, No. 2, p. 57.

with the effect of certain dyes in causing rapid tendering of cellulose fibres. This is discussed in Chapter IV, Section 4, in connection with the fastness of dyeings to light. The comparative intensities of light under various conditions are given in the same section (page 103).

Exposure out-of-doors causes deterioration due to sunlight, micro-organisms, and frequent wetting and drying. Such exposure is known as weathering. It is a feature in the wear of tentings, sun-blinds, awnings, garden-chairs, and also to some extent with window draperies, where the windows are usually left open. In tests [1] on tent ducks made of linen and of cotton, it was found that one year of exposure to weathering in England of unproofed fabric caused a loss of strength of about 50% in both cases.

Heat damage may occur to fabrics more easily than is generally recognised. For instance, cotton fabrics are very seriously tendered, and lessened in wear resistance, by heat damage which may not show as a scorch. Such damage may occur very readily at low temperature if the sizing in cotton fabrics contains certain chemicals, such as Epsom salts. These chemicals are added to the sizing to add weight to the cloth by keeping up the moisture content. Overheating sufficient to cause damage may easily occur when goods are being dried in front of a hot fire, or hot-ironed either too long or when they are dry. Complaints have occurred concerning trouserings containing effect stripes of silk or of mercerised cotton where such stripes have disappeared in wear. Investigation proved the cause was due to heat damage; in

[1] *First Report of Fabric Co-ordinating Committee*, 1925. Pp. 54–60.

one case it was due to pressing the trousers directly with a hot iron, in other cases it was the consequence of standing with the back to a fire or a radiator.

The matter of moth damage requires brief consideration. In the first place the damage is not done by the adult clothes moth, which is a small four-winged golden-coloured flying insect (see Fig. 32). The female adult moth lays eggs and these develop

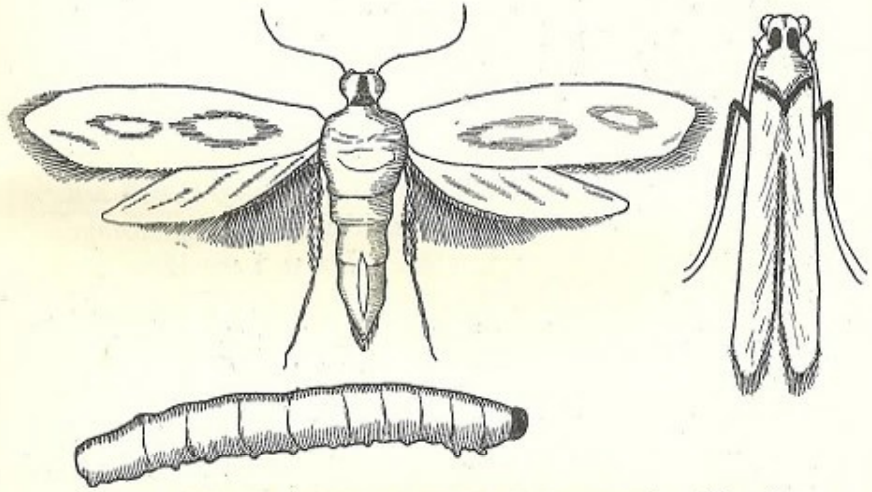


Fig. 32.—Enlarged drawings of the clothes moth, with wings open and closed, and of the moth grub, which actually causes the damage to fabrics.

into small grubs which feed voraciously and do the damage. The eggs are oval and about 0.01–0.015 inches wide by 0.02–0.03 inches long. The grubs are at first very minute, say about one twenty-fifth of an inch long, and they grow to about one-half inch in length before they pupate (form chrysalids). The grubs can only feed on wool, fur and feather; they cannot attack any other fibres. They prefer loose wool to woven wool, and so they are more likely to eat the hairy nap on a cloth (say a blanket) and leave the

woven part unaffected; and they will attack loosely woven material in preference to fabric made of well twisted yarns or of tightly woven structure. During the warm part of the year (say April to October) the eggs hatch out in 7 to 10 days. During wintry conditions the eggs lie dormant. The illustration in Fig. 33 shows the wool pile of a carpet after attack by clothes moth grubs.

Various processes for moth-proofing woollens have been developed; they are based on the impregnation of the fibre with some chemical poisonous to the moth larvæ, but not objectionable to humans.

The eggs of the clothes moth are very fragile and beating or exposure to heat (such as sunlight) will kill them. Moth-proof bags are sold for the safe storage of woollen and fur garments. These bags keep out the clothes moth, but if the fabrics are stored away with eggs already laid in them serious damage may occur. Some chemical which will kill the larvæ if they hatch out should be enclosed. Old-fashioned preventatives are camphor and moth-balls (naphthalene). These are odorous substances which vaporise easily, and yet the vapours will easily condense again in cooler conditions. Probably fabrics stored away with camphor or naphthalene get ultimately a fine coating of small crystals on each fibre, and this poisons the food of the moth larvæ. A chemical much used in moth-killers is called para-dichlorobenzene. It has a smell somewhat similar to that of camphor or naphthalene, but rather more intense, and its vapours are probably directly toxic to the larvæ.

Section 7

Shrinkage.—Some people believe that only

woollen fabrics can shrink; laundries and many housewives know from bitter experience that any fabric may shrink to an objectionable extent.

YOU ARE SHOWN AN ALBUM OF ENTICING PATTERNS
CAREFUL MEASUREMENTS ARE TAKEN.
IF YOU VENTURE TO EXPRESS A MILD HOPE THAT THE SHIRTS WILL FIT, YOU EVOKE A SUPERIOR SMILE
THEY COME HOME, AND ARE SATISFACTORY—
—UNTIL THEY HAVE BEEN TO THE LAUNDRY.
ON COMPLAINING TO THE MAKERS, YOU GATHER THAT SHIRTS ARE NOT MEANT TO BE WASHED!
AH! THEY'RE BOUND TO SHRINK IF THEY'RE WASHED
W. K. HASELDEN

Fig. 34.—A cartoon humorously illustrating the shrinkage problem with shirting.
(Courtesy of the "Daily Mirror" Newspapers, Ltd.)

When fabrics or garments are wet they can be stretched to an appreciable extent, and if they are dried while in this stretched state, they remain enlarged until they become wet again, when they slowly revert to the natural size.

In the various processes of bleaching and dyeing, lengths of fabric are joined end to end to form a long rope. During the process of running this rope from one vat to another in the treatments, the weight of the wet rope of fabric is great enough to cause some increase in the length of the fabric. If the fabric is then rapidly dried this stretch is set, and remains till the fabric is washed. Such " outcome " of the fabric, as it is called, may be 3% to 5%, and so it is not uncommon to find this degree of length shrinkage in cloths.

A finish given to some cloths to secure a special appearance or handle is the " crab " finish. This process is one of straightening out the warp threads in a cloth by a tension along the length. Except in a special case such a finish means trouble when the fabric gets wet. During crabbing the fabric will decrease in width, but increase in length. On washing a garment made from such a fabric there will be the reversion, causing an increase in width and a decrease in length. This, of course, spoils the garment for future wear. A cotton-rayon fabric examined by the author had been crab finished. When washed the cloth increased $7\frac{1}{2}\%$ in width and decreased 11% in length. This cloth must have given rise to very severe disappointment in the customers who made it into washing frocks.

The special case where the crab finish does not normally mean shrinkage is with woollen goods. The

wool fibre can be stretched to a very considerable extent, but it ordinarily has a perfect elasticity, that is to say it recovers completely on standing. It is for this reason that creased woollen fabrics straighten out when stored away for a short time. But, if while wool is stretched it is heated by wet steam, or kept in hot water near to the boiling point, then a change takes place in the fibre and a permanent stretch is secured. This principle is used in permanent hairwaving. Crab finishing of woollen fabrics straightens out the cloth and improves the lustre. Under ordinary circumstances the stretch or " set " is permanent. Recovery to normal size occurs if the fabric is left in hot water, or if it is exposed to the action of alkalis.[1] Thus a dress fabric that had been crab finished could be washed quite safely in tepid soap solution ; but if much alkali were present or the solution were hot, then shrinkage (recovery to normal size) would occur.

In the finishing of woven fabrics the drying is performed in a machine called a stenter. This consists of two endless bands having pins or clips which grip the cloth by each selvedge. The cloth is held taut and horizontal, and it is passed through a long chamber where hot-air circulates and dries the fabric. The stenter is legitimately used to apply a small tension across the width to pull the weft threads straight. But it can very easily be used to apply a greater tension, and so to stretch out the fabric while it is wet and to deliver it dry in a stretched state. Some fabrics can be stretched 10% or even more.

During the weaving processes cloth is under various tensions and the result is that during finishing

[1] Speakman. *Nature*, 1929. Vol. 124, p. 948; and *Transactions of the Faraday Society*, 1929. Vol. 25, p. 169.

operations shrinkage occurs. For instance, a cotton fabric 40 inches wide in the loom will only be about 36 inches wide after proper finishing. Now cloth may be transferred from one person to another in the grey, or loom, state and this second person may send it to be dyed and finished. The finisher usually asks at what width the cloth is to be finished, and the owner of the cloth is usually very interested in the length " outcome " of the cloth, for it gives him a greater yardage to sell. He may even request it be finished stretched to a considerable extent. Very obviously an offer of a cloth 40 yards long and 40 inches wide appeals very much better than another of 37 yards long and 36 inches wide for the same price. The two could be the same cloth in the loom state ; but one would give serious trouble owing to shrinkage, and the other would never shrink.

This shrinkage of stretched fabrics is a very serious cause of trouble. For instance, a 15 inch collar of a silk shirt measured 13¾ inches after it was washed. It was not now a collar ; it was a choker. In some items such as the neck-bands of shirts, and collars, shrinkage even to a slight degree means discomfort and even ill-health (for a tightly-fitting collar is certainly unhealthy). With a washing frock 40 inches long, a shrinkage of 7½% means 3 inches, which will certainly spoil the frock. A similar width shrinkage will convert a moderately loose frock into an unwearable frock.

One very important point, however, requires consideration. The final finishing operation of most cloths is calendering ; that is to say, the cloth while damp is passed between heated heavy rollers to secure a smooth finish. Now during calendering some slight extension of cloth may take place, and this cannot be

prevented. If, after washing, a fabric is calendered at a laundry, or is smoothed by hot-ironing, while evenly damp, then like conditions are secured and so like extension is probably secured. But if, on the other hand, the fabric is calendered or ironed while it is dry, or only slightly, or unevenly, damp, then like conditions are not secured, and some shrinkage may be found.

In the following table are given the results of some determinations of shrinkage of fabrics when washed, dried and ironed dry, and when similarly treated and ironed while evenly damp. Particularly note that it is advantageous even with woollens to iron while damp. The two fabrics which should not be ironed damp are those of wild silk and of delustred acetate rayon (see pp. 79 and 80).

TABLE NO. 8

Effect of ironing dry and evenly damp on shrinkage of fabrics.

FABRIC.	SHRINKAGE. Ironed dry.		Ironed evenly damp.	
	Width.	*Length.*	*Width.*	*Length.*
Crêpe de chine	13½%	6%	10%	5%
" "	5%	7½%	2½%	6%
" "	12%	5½%	6%	5%
Cotton rayon, plain weave	6%	6½%	Increase 3%	3½%
" " "	10½%	8½%	Increase 3%	3½%
Rayon stockinette	2%	11%	Nil	2½%
Nun's veiling (wool)	4½%	5%	1%	2½%
Wool marocain	23%	5%	13%	Nil
" "	5%	5%	Nil	2%

The figures in Table No. 9 are provided by a London firm which specialises in treating fabric (in the piece) to take up its shrinkage. These fabrics are

treated mainly for the high-class tailoring and men's outfitting trade and so only higher grades of fabrics are concerned. Unfortunately, only length shrinkages are available.

TABLE NO. 9

Length shrinkage of various types of good quality fabrics.

Fabric.	Minimum. %	Maximum. %	Average. %
Poplins	2.7	5.1	3.8
Crêpes	4.8	6.0	5.7
Taffeta	2.7	4.9	4.2
Cotton drills	0.7	3.2	2.1
Longcloth	2.1	2.7	2.6
Spun silk	2.9	3.6	3.2
Super spun silk	4.4	6.6	5.4
Jap silk	4.4	4.8	4.6
Interlining	0.9	3.3	2.1
Hair cloth	2.0	3.2	2.7
High grade woollens	1.9	4.0	2.6
Lower grade woollens	1.4	5.9	3.3

From the retail buyer's point of view it is clearly necessary when comparing values in fabrics that shrinkages shall be known. A process for determining shrinkage is very simple. A portion of cloth is accurately measured and then immersed in warm soapy water, and left for an hour, occasionally squeezing the cloth by hand. It is then rinsed, dried, ironed and measured, and afterwards wetted out again in water, squeezed in a towel to remove excess of water, and again ironed and measured.

So far as the customer is concerned, she is well advised always to anticipate some shrinkage. Before making up fabric it is best to give it a good long wash; this will prevent spoilage of garments or fitted furnishing fabrics by shrinkage. Alternatively, garments or draperies should be made with wide hems and wide turnings of seams that can be let out if necessary.

The preceding remarks have been concerned with woven fabrics, but the same trouble may be met in knit fabrics. Sometimes even makers of unshrinkable wool underwear have been so foolish as to "board out" the garments, so that inevitably shrinkage occurs in the first wash. An example of stretched knit fabric was provided by a stockinette jumper which was originally a comfortable fit, but after it had been soaked in cold water it was so shrunken that it was unwearable. The author has been informed that in the past some manufacturers of men's half-hose only made sizes of 9, 10 and 11 inches, the intermediate $9\frac{1}{2}$, $10\frac{1}{2}$ and $11\frac{1}{2}$ sizes were secured by boarding out. Protests from the retail trade have abolished this foolish practice.

One property of knit fabrics must be mentioned here. Owing to their structure they may easily distort if hung up to dry. A warp knit rayon petticoat was returned with complaint that it had shrunk eight inches in length after washing. Comparison with an unwashed garment showed this was true; but it also showed the washed garment had increased five inches in width. Measurements showed that the areas of the two garments were the same, so no true shrinkage had occurred. Pulling the garment while dry, or even while wet would not increase its length; but dipping it in water and then hanging it on a coat-hanger to dry resulted in a seven inch increase in length, so restoring it to more normal proportions. A second treatment would probably have caused a further increase in length. The distortion and the return to proper shape were both due to the comparatively small, but long continued, tension of the wet weight of the fabric. Knit fabrics are best dried laid out flat.

Section 8

"Unshrinkable Wool" Fabrics.—Ordinary wool possesses the property of "felting," that is, under suitable treatment the fibres become matted, or stick to one another. This property of felting is associated with the scales in the wool fibre. The principle cause is probably an interlocking of the scales, as shown in Fig. 35. A subsidiary cause may be that the scales become softened and have a tendency to fuse together, just as would say two pieces of wet glue if they were pressed together. It is the felting

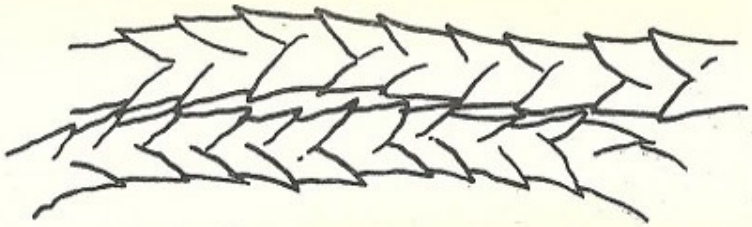


Fig. 35.—Illustrating the interlocking of the scales of two wool fibres. Probably the principal cause of the felting or shrinking of woollen fabrics.

together of the wool fibres in the fabric which produces "thickening" and shrinkage.

Felting can only be produced by rubbing action. It may occur by simple continued rubbing with some fine woollens, but it more readily occurs when the fabric is wet, and it most readily occurs in hot soap solutions. Contrary to general belief boiling in water or soap solution does not of itself produce shrinkage; if no rubbing action occurs, no felting occurs. Also there is no soap which will of itself shrink woollens, but any soap plus rubbing will cause shrinkage. The fact that soap is not necessary is often seen in the felting up of wool socks during wear. In this case the action

of perspiration, and the normal rubbing during walking, are the causes. Wool can be felted by rubbing in an acid solution, and soaps and acids are poles asunder in chemical properties.

It is stated[1] that after bleaching with sulphur dioxide the shrinking or felting properties of wools are increased, and that with wools of small felting power (such as recovered wools or mordanted wools) a treatment with sulphur dioxide is very useful in securing increase in the felting properties. In consequence fabrics made in part of bleached and in part of unbleached wool may give an uneven shrinkage if harshly washed.

Wools also differ widely in their felting properties. In Fig. 36 is shown a portion of a blanket where the white wool weft has shrunk and the coloured weft is unaffected. This may have been due to the use of two different qualities of wool or to the bleaching of the white wool increasing its felting properties.

Many years ago it was discovered that a mild treatment of wool with bleaching powder solution (calcium hypochlorite) and acid made the wool resistant to felting and, carried to the proper stage, it made the wool unfeltable, or fabrics unshrinkable. This process is known as chlorination. As mentioned earlier, excessive treatment with bleaching powder simply destroys the wool.

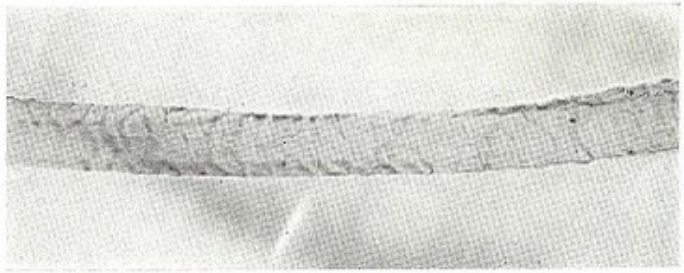
The effects of chlorination depend on the degree of processing. At first the scales close in, and so the edge of the wool fibre in place of being serrated becomes almost smooth; the second stage involves some dissolving away of the scales and the striations on the cortex of the fibre can be seen through the scales;

[1] Lloyd. *Textile Argus*, 1930. Vol. 27, No. 287, p. 50.

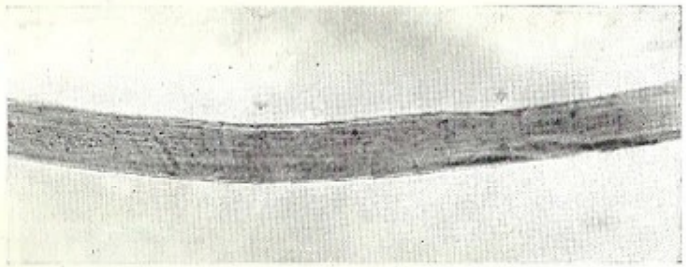
the third stage is typified by the disappearance of the scales and the wool fibre appears as a long cylinder with striations running along the length ; and in the final stage the fibre is corroded by the chlorine and it is very brittle. A normally chlorinated fibre and an over chlorinated fibre are shown in Fig. 37. Comparison should be made with the wool fibre in Fig. 2. The desirable chlorination is to the end of the first stage, for when fibres are in the third stage a fabric has not merely lost its capacity for shrinkage, but it may actually increase in size on washing.

From the preceding statements it will be clear that the processing of wool to make it unshrinkable is one that requires careful control. Different types of wool will respond differently to treatment, and so no simple process following a formula will suffice. Unless special care is taken the wool may receive insufficient processing, and be shrinkable, or may receive too much processing, and have poor wearing properties.

The results of a large scale experiment are therefore of interest. Under-garments of various brands which were sold as "unshrinkable" were submitted to a laundering test. In the first place they were given a prolonged soaking in water in order to remove any shrinkage due to stretching during finishing ; next they were given five launderings (wash, dry and finish) such as would be given in a high class laundry ; then they were given ten launderings of an ordinary type ; and finally they were given the type of laundering they would receive if owing to some accidental sorting at the laundry they were included in the white cotton goods hot wash (but not the boil). The experimental results concerned twenty-one garments, representing seventeen makes or brands. One "guaranteed un-



Normally chlorinated wool fibre.



Over chlorinated wool fibre.

Fig. 37.—Wool fibres normally chlorinated and over chlorinated.

(Courtesy of the British Wool Industries Research Association.)

[To face page 74.

classed as very resistant to shrinkage were actually made of unshrinkable wool, but the area stretch in them was 15% and 10% respectively.

It is often stated that the process of rendering wool unshrinkable destroys the wearing properties and, moreover, that the effect is not permanent. The author has examined three wool, winter-weight vests which were purchased in the autumn of 1924 and worn six months each year ; the three vests had not shrunk or thickened in May, 1930, that is after six years of service, but at the bottom of the back the fabric had worn somewhat thin. They had been washed at different times by many laundries and washerwomen and some of the treatments were known to have been severe. They were still quite serviceable vests. This disposes of both the statements quoted at the commencement of this paragraph.

It is often believed that the presence of cotton in underwear will prevent shrinkage. Certainly it will have some slight tendency to make felting more difficult. But the author has examined very shrunken garments that have contained 75% cotton and only 25% of wool.

The sale, under the description " unshrinkable," of woollens that have not been chlorinated, or that have been inadequately chlorinated, is a fraudulent practice. Unfortunately it is not uncommon. Fig. 39 is given as an illustration of this fact.

One final remark may be made concerning unshrinkable wool. After processing, the wool has a " handle " that is appreciably harsher than ordinary wool. But after washing, chlorinated wool " handles " about as well as ordinary wool.

Fig. 39.—This is a pair of child's socks of a well-advertised brand and marked " unshrinkable " on the foot. One has received rubbing washes in soap and water only until it shrank no more. The wool in these socks had not received any chemical treatment to make it unshrinkable.

[*To face page 76.*

Section 9

Other Factors affecting Washing Wear.—The general question of washing and proper washing processes will be discussed in a later section of this book. But a few points may be considered here, even if some slight repetition is involved at a later stage.

Cotton, linen and cellulose rayon are not damaged by a boiling soap and soda wash. This does not apply to silk, wool, and acetate rayon. Both silk and wool will withstand a very hot wash in pure soap solution without any apparent damage (though some damage does occur and very hot washes are not desirable), but in the presence of soda both are considerably affected. Silk is seriously weakened, and wool first becomes yellow and then of a slimy nature, and it finally loses all its strength and breaks into fragments. In passing, it may be stated that many " dry soap " powders are mixtures of soap and soda. One complaint the author examined was a silk underslip that had been boiled in soap and soda to remove the colour ; the result was disastrous. A case illustrating the damage to wool was that of some wool and rayon combinations ; they were returned from the laundry as rayon combinations with a few slight yellowish patches as the sole indication that wool had been present. They had doubtless received a severe soap and soda wash by getting accidentally included with the cotton goods wash. Acetate rayon is superficially decomposed on boiling even in the purest soap solution, and in consequence the fabric, if coloured, becomes dull and lustreless, or if uncoloured becomes white and cotton-like.

Patent washing powders or liquids are often

dangerous. In many cases if the instructions given are carefully followed, then all may be well, but frequently the instructions are not properly observed. One common constituent of bleaching liquids is hypochlorite and this, if not properly used, will very rapidly tender cotton, linen, and cellulose rayon. If hypochlorites are used on silk or wool they first turn the fabrics yellow and then decompose them. A very heavy Jap silk uniform dress was returned torn and weak after two months of use; chemical tests showed that this was due to hypochlorite bleach. It had been sent to the laundry and treated with the cotton goods which had received a mild bleaching process. Bleaching washing powders usually contain sodium perborate, a chemical which liberates oxygen when it is in a hot solution. This is a far milder bleach in normal conditions. It is the only bleach that can safely be used to refresh silks or woollens that have become yellowish. Damage often occurs through the powder being sprinkled on clothes instead of being dissolved, as the instructions will direct. This means an intense and destructive local action. But in addition the presence of impurities in the fabrics will sometimes cause a severe local action, and so decompose the fibres. Common metallic stains are from iron and copper articles. An experiment was performed, using an oxygen generating wash powder and following the maker's directions. The original strength of the cloth was 161 lbs. on a four inch grab test. A clean piece, given a twenty minutes boil according to the directions, had a strength of 156 lbs.; this small change is within the limit of the experimental error of the machine and the normal strength variations of such fabrics. But a piece stained with iron rust had a strength of only

125 lbs., and one stained with copper had a strength of only 93 lbs.; figures that definitely show severe tendering.

Traces of iron will have serious effects on the wear of white wool, for after a few launderings the wool becomes yellow, or after a short period of exposure to light the yellow colour also develops. Traces of iron on white silk also cause it to become yellow. Such traces of metallic contamination may occur during the manufacture or the finishing of fabrics, if due care is not taken.

Mention has already been made of the risks in hot-ironing rayons; that is, of glazing or melting acetate rayon, and of cutting holes in ordinary rayon. Another point of importance affects silks, for if white silks are smoothed with a very hot iron they become yellow. With wild silks (shantung and tussore) the fabric must be ironed when dry. If ironed damp the material becomes somewhat stiffer and has rather a glazed paper-like appearance. Should the fabric be spotted with water when it is ironed, all these water-spots will shew in the finished material as grease-like patches. Adequate rinsing is also very important. If two pieces of cotton cloth are washed together and one is rinsed thoroughly and the other slightly, it will be found that on smoothing the two side by side under a hot iron the well rinsed will be unaffected, when the slightly rinsed one becomes scorched. The presence of traces of soap or of chemicals in cotton, linen or cellulose rayon means greater risk of yellowing or scorching during hot ironing. Overbleached fabrics, in addition to their other defects, are also more easily scorched.

Finally, there is a risk peculiar to delustred acetate

rayon fabrics. In some fabrics the lustre of the acetate rayon is removed by a boil in soap solution. This gives a pleasing matt effect. But if such fabrics are sprinkled with water and then hot ironed, grease-like spots will appear. Inspection will show that in these areas the acetate rayon has again become lustrous. These fabrics must be ironed when dry or when very slightly and very evenly damp. If spoiled by the grease-like marks the only simple process is to wet them and iron to make lustrous all over. It is, however, possible under proper conditions to reboil them and restore the delustred effect. This, however, could only be done by skilled treatment at a dyeing and cleaning establishment.

CHAPTER IV

COLOUR IN WEAR AND WASH

Section 1

General Remarks.—The greatest single factor in the Appeal of a fabric is probably concerned with the colour effects. The principal factor when defective Utility is concerned, is undoubtedly defective colour-fastness. This subject is, therefore, one of considerable importance.

One point that requires emphasis is that the problem of obtaining a range of reasonably fast colours on fabrics is not immensely difficult. To match any given shade a restricted palette of colours is all that is necessary and the matching of the shade is a simple experiment with the object of ascertaining the correct proportions to be taken of each colour. This colour mixing technique is one all children learn when they first get a box of paints. Theoretically the only requirement is four dyes: a pure red, yellow, blue and black. In practice these " pure " colours are not always available in fast dyes, and so a somewhat larger number of colours is necessary. But the important point is that only a very small number of dyestuffs is necessary, and so if any dyer will make proper selection based on dyeing and fastness tests on the hundreds of dyes available he will not find his research unduly prolonged or expensive.

This is perhaps making the dyer's job in securing

fast colours look more simple than is just. There are, in fact, certain difficulties that creep in from time to time, but as a broad statement the preceding paragraph holds good.

It is also anticipating the question of standards of fastness which will be discussed later, but throughout this chapter it is important to realise that the great requirement is intelligent selection of dyestuffs for use, and often this intelligent selection is clearly lacking on the part of the dyer.

A second point of importance is concerned with the two types of dyestuffs, the artificial or coal-tar dyes and the natural (mainly vegetable) dyes. Certain people believe that for some reason or other the old and natural dyes are the better. They certainly are the more expensive, but it is equally certain there are "coal tar" dyes which are not merely as good, but which are very much better, in spite of the fact that they are cheaper.

In 1856, a young chemist named Perkin sought to make quinine by chemical treatment of aniline oil (a product first obtained from indigo, but which later had been made from coal-tar products). His experiment was a happy failure; for the product was not quinine but a violet powder, which dissolved in water, and was a brilliant dye on silk or on wool. Perkin developed his process commercially, and so started the dye-making industry, which first flourished in this country, then expanded gloriously in Germany, and which is to-day again an industry of great importance in England.

Now this mauve dye which Perkin first made (and many of the early coal-tar dyes which followed it), was of a brilliance in colour far surpassing the natural

dyes, but unfortunately it was not a fast colour; in fact it was very quickly faded by light. In the early stages of the coal-tar dye industry the natural dyes were superior in fastness, if not in brilliance.

But this position did not last. In the eighteen-nineties, research into the chemical composition of indigo, the fastest natural dye, had proved a success and the same dyestuff was made from coal-tar products. Nowadays the compositions of all fast natural dyes are known, and they are made in chemical factories. In fact, some modern dyestuffs are so excellent that the fastest natural dyes appear fleeting and evanescent when compared with them.

An important date in colour-fastness history is 1902. In this year, Mr. James Morton, of Carlisle, a furnishing fabrics manufacturer, saw some fabrics in a London shop window, and they seemed familiar. They were his own designs fearfully altered by fading. Shocked by the rapid spoiling of good fabrics, he procured many samples of furnishing fabrics from shops, and exposed them to sunlight for a week. The result he described as a Flodden Field, for "in many cases quite deep shades on expensive velvets had become almost white in a week."[1] A few colours, however, were more resistant, and Mr. Morton determined that his furnishing fabrics should be fast in colour. In 1904 he placed on the market furnishing fabrics with "guaranteed fast" colours. Then everyone prognosticated disaster for this development in furnishing fabrics. Nowadays almost everyone selling furnishing fabrics describes his own products either as "guaranteed fast" or as "fadeless." The description,

[1] Morton. *Journal of the Royal Society of Arts.* 1929. Vol. 77, p. 544.

meritorious because true in 1904 (and since) of Sundour fabrics, is in danger of being spoiled by unscrupulous people, owing to its fraudulent application to ordinary grade dyeings.

This Mr. Morton is a very determined idealist. When in 1914 he found the supplies of fast dyes cut off by the war, he asked manufacturers in England to make these dyes. They considered it too difficult, so Mr. Morton faced the problem himself, and after immense difficulties was manufacturing fast dyestuffs in late 1915. By the end of the war, Scottish Dyes, Ltd., was a huge factory. In the post-war depression of 1921 most dye manufacturers diminished the number of their chemical staff. Mr. Morton retained all his staff and directed their energies to research, and among other achievements they discovered the fastest dyestuff yet known, Caledon jade green.

Another interesting date in colour-fastness is 1929, when a large Manchester firm started a policy of selling only those fabrics to which they could give an unconditional guarantee of satisfaction. This guarantee is based on the work of a large testing and research organisation, and it covers not only the colour but also all other qualities of the fabric, such as strength, shrinkage and slippage. The fabrics cover a very wide range in cotton and rayon materials, and in 1930 this firm was the first to introduce vat-dyed piece-dyed silks.

Section 2

Dyestuffs and Dyeing.—To understand colour-fastness problems some knowledge of dyestuffs and dyeing is very desirable. In this section the types of

dyestuffs and the principles of application will be described briefly.

Many dyestuffs dissolve in water, giving strongly coloured solutions which will colour untreated cotton, but the colour is all, or nearly all, loose to water and so the cotton cannot truly be considered as dyed. For this reason the dyestuffs which possess the property of truly dyeing untreated cotton (that is giving colours fast to water at the least) are known as *Direct Cotton dyes*. These dyestuffs can be used on all cellulose fabrics and on silk and wool. They are generally of a reasonable fastness to light, washing and perspiration ; some are very fugitive, but, on the other hand, some recent direct cotton dyes are of very great fastness to light and they are used on so-called " fadeless " furnishing fabrics.

The next two classes of dyes are very effective on wool or silk, but not on normal cotton. These types are known as basic dyes and acid dyes. The names are derived from the chemical constitution. In some cases they will dye a union fabric, leaving the cotton not even tinted. As a class the *Basic dyes* are characterised by their great brilliancy ; they have a beauty not met with in any other class of dyes. But unfortunately they have also a serious disadvantage, for they are generally very fugitive to sunlight. Basic dyeings on silk give beauty that is suitable for evening wear, but not for day wear. These basic dyes are not infrequently used on silks. The *Acid dyes*, however, give colours of good fastness to light, and they are also good, clear, bright colours. But alkalis do not agree with acid dyes, and in fact a test for an acid dyeing is to determine how far the colour is extracted from the fabric by boiling in alkali, usually

ammonia. Now all soap solutions are alkaline (some to a small extent, some to a large extent) and so acid dyes generally are not very fast to washing. Some, however, are fast enough for use in ordinary grade washing fabrics. Acid dyes are frequently used on woollens, such as dress goods, carpets and bathing costumes, and also on silk, where colours of reasonable fastness to light are required.

Another class of dyestuffs is the *Mordant dyes*. These are dyes which combine with certain chemicals and give a colour of superior fastness to those types already mentioned. The mordants commonly used to fix the dyes are compounds of chromium, aluminium or iron (such as potassium bichromate, alum, and iron sulphate) or tannic acid. There are three types of mordant dyeing : the fabric may first be treated in the mordant liquor and afterwards in the dye-bath ; or, the mordant and dye can both be dissolved in the bath and applied at the same time ; or, the fabric may be dyed in one treatment, and then after-treated in a mordant bath (usually by adding mordant chemicals to the same bath) to secure a faster colour. A more recent development has been to make a metallic compound of dye and mordant and to use this direct. Fast colours on wool are usually mordant dyes. By treating cotton with mordanting chemicals it is possible to get satisfactory dyeings with basic or mordant dyestuffs. One very well-known mordant dye is alizarin. This dye is well known for its fastness to washing, light and other factors of wear. Alizarin is the name of one particular dyestuff, but nowadays the term " alizarine dyed " is often used for any mordant dyeing of good all-round fastness.

At this point it is opportune to make a few remarks on the possibility of fixing loose dyeings. Sometimes a treatment in a mordant bath will have some effect. The author has cured some bathing costumes which had loose colour by mordanting with bichromate or with alum. The only other methods of fixing depend on either rectifying defective dyeing, or restoring loosened dye ; for instance, if in the dyeing operations the cloth has not been treated for long enough in the dye-bath, or has not been properly rinsed after dyeing, it is possible to do this later ; or, if say an acid dye has been loosened by contact with alkali, then often it may be refixed by heating it up again in an acid solution. In general, however, loose dyes cannot be " fixed." Dyeings to be satisfactory must be so dyed from the start.

The *Vat dyes* are the most important. The first well known vat dye was indigo. Originally this was extracted from the indigo plant. Nowadays it is usually made from coal-tar products. Indigo is a blue powder which is insoluble in water and possesses no dyeing properties ; but if placed in a vat in which a certain type of fermentation is taking place, it is deprived of some oxygen and changed to a white substance which will dissolve if some weak alkali such as lime be present. Hence the term vat dye. Nowadays in place of a complicated fermentation vat, a suitable chemical solution is used. In ordinary conditions it is not possible completely to remove oxygen, and so the dye liquor is usually a greenish-yellow colour. If wool fabric is heated in this solution it is dyed, though no apparent change can be seen until the fabric is taken out into the air, when the white form of the indigo absorbs oxygen and

becomes blue again by forming insoluble particles of blue indigo right inside the fibres.

There are two types of vat dyes now known. One class is similar in chemical constitution to indigo and the second type is of different chemical structure and is known as Anthracene vat dyes, or in Germany as Indanthrene dyes. The second type includes the fastest dyestuffs known, and dyes of this type are generally faster than the Indigoid vat dyes. The vat dyes require an alkaline solution, and in consequence they are not well adapted for dyeing silk and wool, for these fabrics are damaged by alkali. Until recently the only vat dye used on wool was indigo. Early in 1930 the author was shown a range of colours on wool cloths that had been dyed with indigoid vat dyes under special conditions. This produced a "fadeless" wool cloth. Moreover, owing to the nature of the dye-bath conditions required the wool fabric was actually stronger than its equivalent in ordinary dyed woollens. It has also proved possible to secure level dyeings in the piece on silk, using the same processes. Prior to this vat dyes on silks had been restricted to yarn dyed silks; now it is possible to send silk in the cloth to be dyed in a wide range of "fadeless" colours. This will have a great effect on the silk trade. It should prove especially useful on shantung in producing coloured silk window drapery. Ordinary silk is not suited for this purpose (see page 58).

Another class of insoluble dyes is the *Sulphur dyes*. These are made soluble in a chemical vat and regenerated by air just as are the vat dyes. They are colours very fast to washing and perspiration, and of good fastness to light, but not generally of the "fadeless" class. As mentioned earlier (see page 36) they

are liable to oxidation (particularly the black colours), producing sulphuric acid, which in turn rots the fabric.

An interesting class of dyestuff is the *Diazotized and Developed dyes*. Here the fabric is impregnated with a substance (which may actually be a dye) and then by chemical processes this is made to combine with other substances, producing a colour actually in the fabric itself. Some of the colours so produced are nearly as fast as good vat dyes.

The most recent problem of the dye-maker and dyer was to dye acetate rayon. Ordinary dyestuffs do not generally affect this fabric. A solution of the problem was found in dyes which are insoluble in water, but soluble in cellulose acetate. So if acetate rayon is immersed in water containing a suspension of very small particles of this type of dye, it dissolves the dye and is coloured. This type of dyeing is usually very fast to washing and perspiration, but variable so far as light-fastness is concerned.

Finally, we have various odd methods of dyeing. Mineral matters may be formed on and in the fibres, such as mineral khaki (using iron and chromium salts) or a black by forming an ink using tannic acid and an iron solution.

Section 3

Dyeing Processes.—Coloured fabrics may have been dyed when they were in the state of loose fibre, or in the yarn, or in the piece.

Dyeing in the fibre state is generally necessary when yarns containing blended colours are required. Yarn dyeing is necessary where a pattern is woven in the fabric, as say with ginghams, damasks, tapestries and carpets, and it is sometimes advantageous in self-coloured fabrics (i.e. fabrics with plain single colours),

for often a more even penetration of colour can be secured than is possible in piece dyeing. For instance, if yarns are removed from a vat-dyed piece-dyed fabric, very frequently light coloured or even white portions will be seen along the yarn where it has been overlapped by other yarns. In fact, the presence of these slightly dyed portions in yarns can be taken as some evidence in proof that the fabric was vat-dyed in the piece, for ordinary dyes penetrate the yarn more evenly and so do not give such obvious effects. Piece dyeing is, of course, advantageous in several ways. The wastage of fibre which occurs in spinning, or of yarn in weaving has not the additional value due to dyeing. Any stains on the cloth during manufacture can be removed by suitable methods without fear of injuring the colour. And finally stocks can be held in the raw manufactured state, and dyed to the colours in demand.

Many people imagine that the term yarn dyed (or ingrain dyed) means fast dyed. This does not necessarily follow. Obviously yarn dyed fabrics must have colour sufficiently fixed to resist subsequent manufacturing and finishing operations, but these conditions do not include factors met in wear, such as light and perspiration. For instance, not all ginghams can correctly be described as "fast dyed," though all have to be woven from dyed yarns. It is, however, a fact that yarn dyeings are usually fast dyeings.

Plain colour piece dyeing is effected either by continually circulating lengths of cloth joined into an endless rope through the dye liquor and then over a winch which revolves above the dye vat, or by "jig" dyeing, in which the cloth is passed in the flat open state from one roller to another through the dye liquor.

A dye vat and winch is shown in Fig. 40. The dye liquor is gradually heated up to the right temperature and the process of dyeing usually takes 1–2 hours. After dyeing the fabric is well washed in water in the same or another vat in order to remove all loose colour. Two colour effects can be secured in piece dyeing if two types of fibre are present and suitable dyes are used. For instance, in a wool and cotton union fabric, acid dyes may only dye the wool, leaving the cotton white; some acid dyes will tint the cotton slightly, but others will leave the cotton unaffected. With acetate rayon unions with other fibres, one dye bath may contain an acetate dye and an ordinary dye, so dyeing the acetate rayon one colour and the other fibre another colour in one operation.

Printing can be of several types. In direct printing the dye is applied as a paste containing starch or gum as a thickener, and any other chemicals necessary. Where mordant dyes are used the fabric must be mordanted first and then printed with the dye paste. In discharge printing the fabric is first dyed a self-colour, and then a paste containing chemicals that discharge (or bleach) the colour is over-printed, and the discharge is secured by heating the cloth in dry steam. Resist printing is a process of treating portions of the cloth with some preparation, so that in piece dyeing these portions are not affected; printing a wax on to the fabric is one method. Finally, designs can be secured on a fabric by stencilling, using an air-spray for applying the dye-solution. As practically all dyes can be applied by printing, colours of excellent fastness can be obtained.

One point concerning discharge printed fabrics is that the discharged areas have received an extra treat-

ment, and this treatment may adversely affect the fibres if unsuitable chemicals are used. Objection should not be raised against slight tendering due to this cause, but sometimes the tendering may be excessive. Print crêpe de chine frocks have been returned where the white areas have worn very badly, or even fallen completely away, while the coloured portions were still strong (see Fig. 41). The damage occurs where frictional wear is likely, for instance on the elbows, immediately under the arms and at the back of the skirt. In such cases simple hand tests may prove that the discharge printing has caused excessive tendering. Usually the discharge printed portion will be the first to show signs of wear, but if the coloured portions are also definitely weakened by wear the printing process should not be blamed.

Printing can either be done by using engraved rollers, or by raised blocks on rollers. With engraved rollers the colour is fed on to the printing cylinders by smooth rollers and the excess of colour is scraped off by a knife (called a "doctor") before it is printed on to the fabric. This makes a difference between engraved roller printing and rotary block printing. In the engraved roller the doctor blade removes colour from the smooth surfaces, but leaves colour in the recesses for transfer to the fabric. It is impossible completely to remove the colour from the smooth surfaces by means of the doctor blade, and so traces get transferred to the fabric outside the design. If a design requires eight different colours to produce the required effect, then the fabric is successively printed by eight rollers; each colour, therefore, gets a slight contamination with each of the other seven colours. The result is to produce

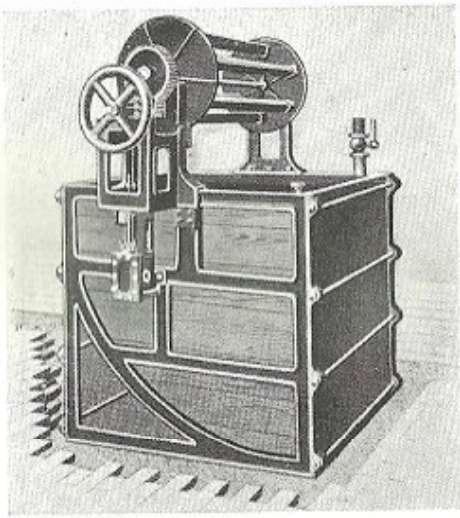


Fig. 40.—Dye vat and winch.
(Courtesy of Sellers & Co. (Huddersfield), Ltd.)

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Fig. 41.—The white rings in this silk crêpe de chine were secured by discharge printing which tendered the silk. The portion shown was from the front of a frock where the knees had caused the fabric to chafe against some object (such as a desk). The fabric outside the discharge printed areas was still of normal strength.

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a slight but appreciable dulling of the colour. With rotary blocks the design is on raised surfaces, and so this slight over-printing does not occur, and brighter coloured prints are obtained.

There are difficulties in applying vat dyes by rotary block printing. But recently these have been overcome and so " fadeless " prints are available in clearer, brighter colours than were ever possible a few years ago.

Defective dyeing may occur for various reasons.

Some dyes have a very great affinity for the fibres, and in consequence they are rapidly absorbed. This tends to produce streaky or patchy dyeing, as it is very difficult in such cases to ensure that all parts of the fabric shall be equally exposed to the dye liquor. For this reason the dyer desires dyes that are " level " dyeing. This is reasonable, but it may happen that to secure a colour with a fast dye requires special care to prevent patchy dyeing, and to avoid this trouble the dyer may use a dyestuff of inferior fastness. On one occasion the author wrote to a large firm of dyers, stating that the blue colour on a rayon dress fabric was so fugitive to light that it was unfit for sale ; the excuse advanced was that the dyers had to use level dyeing dyestuffs. A very inadequate and unsatisfactory explanation.

Another defect met with in dyed fabrics is that of bars across the material, where the colour is lighter or darker. These bars may correspond to the use of a new shuttle of weft. The trouble may be observed in Jap silks, and is still more common in rayon fabrics. It is owing to the yarns differing slightly either chemically or physically. To some extent by the proper selection of dyestuffs this uneven dyeing can be

overcome. But the proper place for the elimination of barriness is in the manufacture of the yarn or in the weaving. For instance, in weaving if two or more shuttles of weft are used, giving alternate weft threads of each yarn, then no barry effect will appear in the dyeing.

The presence of mildew stains or oil stains on a fabric may not be obvious until dyeing has occurred, but then discoloured patches will appear.

On an average it requires about 2 lbs. of dyestuff to colour 100 lbs. of cloth to a medium shade and about 5 lbs. for a dark shade. Ordinary dyestuffs cost from 2s. to 5s. per lb., and the vat dyestuffs cost from 10s. to 20s. per lb. Taking 100 lbs. of cotton cloth 36 inches wide as giving 500 yards, this means the dyestuff cost per yard varies from, say, one-tenth of a penny to twopence halfpenny. In actual dyeing the total cost per yard (dyes, chemicals, steam, plant charges, labour, etc.) for self-colours in ordinary quality is about one penny to threehalfpence, for fast dyeings (mordant dyeings) the cost will be about twopence to threepence, and for vat (fadeless) dyeings about threepence to fivepence. In special cases the dyeing costs may be greater than these figures. But it will be realised that there should not be a great margin in price per yard between good and bad quality dyeing.

Section 4

Factors Affecting Colour-Fastness.—The *Art* and craftsmanship of the dyer is concerned with the production of colour effects and designs, but there is another aspect, not sufficiently studied, namely the *Science* of dyeing, which should be concerned very largely with the fastness of the colour effects obtained.

It will be convenient here to give a table of the various factors that may affect colours on fabrics, and in studying this table it is essential to realise that a colour may be very fast to one factor (say sunlight), but of any degree of fastness to other factors such as, say, washing.

Table No. 11

Factors that affect colours.

Rubbing—dry	Laundering (use of bleach).
—wet	Sunlight.
Water —colour loss ...	Weathering (effect of air and rain).
—water-marking.	
Washing—colour loss ...	Micro-organisms (mildew).
—bleeding (running)	Street-mud.
—marking off ...	Perspiration—colour change.
Alkalis	—bleeding.
Hot-ironing—colour change...	Alcohol and perfumes.
—marking off ...	Fumigation and chemical fumes.
	Acids.

From the above table it is clear that when the term "fast-dye" is used it is essential to know whether this fastness is restricted to some one factor, or whether it applies to several factors, or to all factors.

For convenience in expressing the degree of fastness of colours some system of grading is required. The system used by the author is based on that of the "Colour Index" of the Society of Dyers and Colourists. The fastest colours are Grade 1, the loosest ordinary dyeing is Grade 5, and where colours are still looser they are graded "Not Fast," that is outside any reasonable grading of fastness. This grading is made as consistent as possible and can be interpreted :

Grade 1. The harshest normal conditions have no effect.

Grade 2. The harshest normal conditions have slight effect.
,, 3. Ordinary conditions have slight effect.
,, 4. Ordinary conditions have distinct effect.
,, 5. Ordinary conditions have considerable effect.
Not Fast. Very mild conditions have distinct effect.

A very thorough investigation of the factors affecting colour fastness and the best methods of testing was started in 1928 by the Society of Dyers and Colourists and the Wool Industries Research Association. When the results of these long and exhaustive researches are published, they will give to the dyer knowledge which should prove of the greatest value in classifying dyes and securing fast dyeings.

Now consideration can be paid to the various factors mentioned in Table No. 11.

The first test for a colour is fastness to *Rubbing*, and this is performed by rubbing the coloured fabric vigorously with a white cloth, and the test is divided into two sections, dry rubbing and wet rubbing. Fabrics with colour loose to dry rubbing are usually very objectionable, as other fabrics or the skin will easily become stained. Looseness to wet rubbing is often a serious objection. One complaint examined concerned a red artificial rose. The velvet petals at the back had colour loose to dry rubbing and very loose to wet rubbing (see Fig. 42). This rose, during wear, badly stained a coat lining and a blouse. Another example was provided by some art serge. The colour was loose to dry rubbing, and more so to wet rubbing. The fabric was used to spread over a card table and the sleeves and front portion of the white satin frock which a lady was wearing became

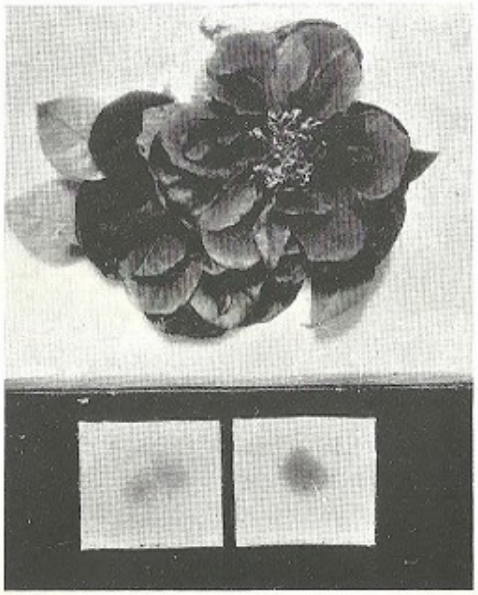

Fig. 42.—Colour loose to rubbing in an artificial rose. The portions of white fabric show the stains produced with dry rubbing and wet rubbing.

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deeply coloured. In buying coloured goods the rubbing test is easily applied, and it should always be used.

A matter of some importance arises at this stage. Many people believe that loose dye is dangerous because it may poison the skin, and, more particularly, that it is especially dangerous if the skin is broken. This belief is not founded on any true experience. The author has had occasion to make enquiry into this matter. Neither he, nor others of much longer experience, have encountered a case of skin poisoning due to loose ordinary dyestuff from textile fabrics. Loose dyes can cause great annoyance, loss, or inconvenience, but they are not likely to be toxic or irritant to the skin. In actual fact certain dyestuffs have proved to possess very great value in medicine owing to their germicidal properties. Dyestuffs are often used artificially to colour foodstuffs, and of the many hundreds of dyes known, the British Government only finds five which are objectionable[1] even for this purpose. In cases of alleged poisoning from dyes on textiles fabrics, it will often be found that there has been an abrasion of the skin and no care has been taken to cleanse and disinfect the wound. The ill-effects have been due to microbes and not to dyestuffs.

The only type of dyeing known to cause skin irritation is a special type used on furs. The ordinary dyes cannot be used on furs as the skin will not stand the heating necessary to fix the dye. So the furs are impregnated with a chemical which on treatment with hydrogen peroxide develops grey, brown, blue-black or black colours. This type of dyeing is very different from

[1] Public Health (Preservatives, etc., in Food) Regulations, 1925.

the ordinary dyeing, as will be realised. A few people possess the idiosyncracy that fur dyes cause an irritation known as "fur-dye dermatitis."[1] Trouble due to this complaint is rare, as can be judged by the enquiry the author made, which showed that complaints due to fur dermatitis are of the order of five per ten thousand of dyed furs sold.

The next consideration is fastness to *Water*. Colour loose to wet rubbing may be found to be appreciably extracted by cold water. Such cases have been met in umbrella covers which have shed coloured rain-water in a storm, and have stained hats and coats. Defective umbrella covers of this type are fortunately rare. But the defect may be met in some printed silks, and it is not rare to receive complaints of water-loose colour in wool bathing costumes. Some dyeings are so affected by water that any drops spilled on the fabric extract colour that gives a dark edge round the water stain. A brown satin grenadine (see Fig. 43) was of this type. It had colour fast to rubbing, but drops of water had a pronounced effect. After washing the spots disappeared, only to come again when spotted by water. This is mentioned because in some cases apparent looseness of dye may be found owing to the fact that water spots will affect the surface or the finish of the fabric; in such cases either brushing or washing will give a permanent cure. Fabrics with water-loose colours of this type are naturally very easily stained; complaints due to this cause have been met in frocks, coat-linings, bed-jackets and eiderdown covers.

Most fabrics during their existence are exposed

[1] See Reports on Public Health and Medical Subjects, No. 27. Fur Dermatitis. H.M. Stationery Office, 1924.

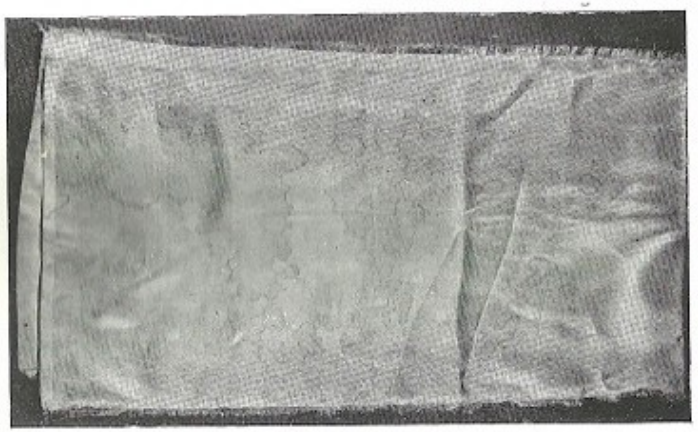

Fig. 43.—The irregular markings on the silk satin are due to water marks owing to the defective fastness of the dyestuff which was used to colour it.

[*To face page* 98.

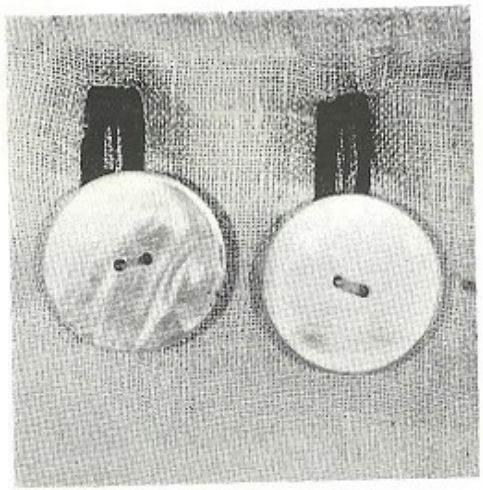

Fig. 44.—The colour on the trimming of the buttonholes of a garment was not fast to an ordinary washing treatment and has bled into the surrounding fabric.

Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

[*To face page 99.*

occasionally or frequently to *Washing*. Sensible people usually wash coloured fabrics under the mildest possible conditions. But, on the other hand, if fabrics are sold as washing fabrics they should withstand even a rather severe ordinary washing, and if they are sold as " fast " or " fadeless " they should withstand severe treatment.

It is a very simple test to wash a sample of fabric, and it is certain that if this were done many disappointments would be eliminated. There are far too many fabrics that fall down seriously in washing. If possible, laboratory tests should always be made, because colours may be satisfactory in a trial wash and fail in use.

An illustrative case was some blue " washing " schappe silk. Its merits were indicated by the fact that a test piece after receiving a laundry wash was returned a light grey colour. Obviously not a washing colour ! But with one ordinary careful wash this fabric would probably appear quite satisfactory. The dye in this fabric was an indicator ; that is to say, it had different colour according to whether it had been in contact with an acid or an alkali. It was blue in the acid state and very light grey in the alkaline state. Simple treatment with acid would restore its colour. The laundry used soap and soda, but all soap solutions are alkaline and would slowly or quickly affect this colour. In another case beige coloured silk hose became somewhat reddish brown after one ordinary wash in soap-flakes. The reason was clear when a portion had been tested in alkali, for it became a bright reddish brown. *Alkali* sensitive colours are absolutely unsuitable on washing fabrics, and so proper washing tests must always include tests for fastness to alkali.

Other points of importance in testing washing fastness are colour bleeding (or running) and colour marking-off. In testing the colour-fastness to washing a portion of white material of similar composition is sewn on to the test piece. Some dyes which are extracted in washing do not cause staining on the white test piece, but in other cases staining slight or serious will occur. The degree of this bleeding must be considered in gauging the washing fastness. The term marking-off is used to distinguish a rather different effect. Some colours are very fast to washing and do not bleed under ordinary circumstances, but if they are left in very close contact with other fabrics while both are wet, then some transfer of colour will occur. This is a very severe test and even many of the very fast vat dyes fail under it. In normal circumstances colours which pass the bleeding test are quite satisfactory ; but for a rigidly " guaranteed fast " line of fabrics only those which are of the best procurable fastness to the marking-off test should be sold. Fabrics may be tested very simply for these types of colour transfer. A strip of coloured fabric and a strip of white fabric are placed back to back, wetted and then wrapped round a pencil, forming several thicknesses of cloth, and left standing for an hour. This will show if bleeding occurs in the wet condition. The test may be repeated (after loosely binding the fabric), either immersed in water or soap water or boiling soap water for one hour. The test in a boiling soap solution is a very severe one and very few dyes will resist it.

While discussing this question of fastness to washing it is convenient to refer to one unusual and puzzling case. Silk hose have been returned by

customers with complaint concerning the development of streaks along the length of the hose. These streaks were frequently of a greenish colour. Experiment proved these streaks were not due to careless washing, or alkali sensitive colours, and enquiry showed many people had washed hose of the same lot and colour without complaint. Finally, it was discovered the streaky portions were very faintly acid compared with the rest of the hose, and this solved the mystery and found the cure. After dyeing, the hose had been scrooped (see page 22) with weak acid, and with a short washing process this acid was not completely removed. In drying, this acid was left in the portions that dried last and it affected the colour. If the first wash had been a long one all the acid would have been neutralised and streaks would not have occurred. By leaving the hose for several hours in a tepid soap solution, or for a shorter period in a fairly strong ammonia solution, the acid was all neutralised and the streaks disappeared.

Dyestuffs are very complicated chemical compounds, and in many cases the colour is affected by *Hot-ironing*. Sometimes the colour change is only temporary and after a short time it reverts to its original shade. This is most frequent with mauve colours which become reddish. Occasionally it is permanent. There is rather a difficulty in setting a standard in this case, because the temperature of an iron may vary widely and, of course, a scorching temperature will spoil the fabric, and nearly always affect the colour. But if the colour is permanently affected by a moderately hot iron, then it is certainly defective.

A matter of some importance in regard to hot-ironing is the transfer of colour to other fabrics in

this process. For instance, in a print frock it is difficult to iron without different portions of the fabric being in contact If colour transfers from the one to the other, the fabric is spoiled. Test must, therefore, be made by hot-ironing the fabric against white fabric, first when both are dry and then when both are damp. This test should be done not only on new fabric, for in the case of acid dyes the colour may be fast at first, but after washing the alkalinity of the soap-liquor may so loosen the dye that it will then print off on hot-ironing.

The loosening of acid dyes by soap may sometimes affect suitings and dress fabrics. In one complaint it was found that a skirt had been made from a wool fabric of twofold yarns, one yarn white and the other blue. On pressing the seams, unsightly blue patches had developed. The wool was coloured with an acid dyestuff and the seams had been soaped before pressing. This had loosened the colour which had spread in the pressing process. As the treatment is not an unusual one the complaint was just, and the fabric was adjudged faulty.

This subject of washing leads to that of laundering. In certain cases to secure good whiteness laundries have to use bleaching agents. Naturally these are not used on ordinary coloured fabrics. But in the case of shirtings, handkerchiefs, tablecloths and towels bleach may be used. Colours that are perfectly fast to soap and soda may not be fast to *Chlorine* bleach (sodium hypochlorite), and so, on these items, the colour is tested, not only for fastness to light, perspiration, washing, alkali and hot-ironing, but also to chlorine bleaching.

In regard to *Sunlight* it is important to note that

conditions of exposure have a great effect. It is an established fact that some coloured fabrics may fade far more rapidly in say, Manchester, than in the tropics. The essential factor in the fading is sunlight, but a very important auxiliary factor in many cases is the moisture of the fabric, and so in moist climates (and, of course, particularly by the sea) fading occurs much more readily. This, by the way, is probably the meaning of the " sea and air " part of the usual claim of " fast to sun, sea and air."

The sunlight which causes colour fading is not simply direct sunshine with its ultra-violet light. The ordinary bright diffused daylight plays an important part in fading. When tests were made by exposing samples, some to direct sunlight, others covered with ordinary window glass (which absorbs much of the ultra-violet light), and others covered with Vita glass, it was found that in many cases the fading was about equal.[1]

With reference to the intensity of light available for fading, measurements have shown[2] that as regards the fading of objects in a museum, the ordinary diffused daylight is about six times as injurious as electric light; and direct sunshine is twenty to seventy times as injurious as ordinary diffused daylight. Other measurements[3] have shown that, even on a dull day at Rangoon, the tropical light is slightly more intense than that of a bright sunny day in the British Isles, while on a bright sunny day it may be from five to six and a half times as intense. These figures should also be considered in relation to sunlight tendering discussed on pages 56-59.

[1] Proceedings Amer. Assoc. of Textile Chemists and Colourists. *American Dyestuffs Reporter*, June 25, 1928.
[2] Harmer. *Journal of the Royal Society of Arts*, 1923. Vol. 71, p. 144.
[3] Teegan and Rendall. *Nature*, 1930. Vol. 125, p. 447.

The action of light usually involves loss of colour, but on occasion a darkening of colour may occur. In ordinary cases of fading the loss of colour is continuous and proportional to the exposure. With some vat dyeings a slight loss of colour may occur after a short exposure, but this loss does not increase on further exposure. In testing the fastness of colour it is, therefore, not sufficient to take the time to first visible fading, but the effect of further exposure must also be considered.

It is very much more difficult to get fast-to-light colours in pale shades than in deep shades and the reason is obvious. If a fabric of a pale shade contains 0.2% of dye and of a deep shade contains 5% of dye and both are exposed to light which destroys 0.1% of the dye, then in one case 50% of the colour is lost and fading is evident, and in the other case 2% of the colour is lost and this would not be appreciable.

The grading the author uses is based on the following scale : [1] (1) no alteration, (2) slight alteration after exposure to one month of strong summer sunlight, (3) slight alteration after fourteen days' exposure, (4) slight alteration after seven days' exposure, (5) distinct loss after seven days' exposure, and slight alteration after three days' exposure.

Experience has shown that complaints of fading against fabrics exposed to outdoor wear are concerned most frequently with colours which are grade Not Fast or grade 5, and to a lesser extent grade 4. As an ordinary grade of fastness (which can be obtained without great difficulty) grade 3 is required.

The testing of light-fastness can either be done by actual exposure to sunlight, or an artificial sunlight

[1] *Colour Index*, Society of Dyers and Colourists. 1925.

(ultra-violet light apparatus) can be used. For practical testing artificial light is essential. The total exposure given in the ultra-violet light apparatus used by the author is one week, if it is necessary to make sure the colours are grade 1.

As an example of rapid fading, some blue spun rayon fabric can be mentioned ; one portion was exposed facing south to the summer sun for one day only and the fading was very distinct. In another case a large consignment of gingham was offered as " fadeless." Test showed it to be of low fastness, and three days' exposure at a window caused very considerable loss of colour. A green rayon jumper was light fugitive in colour and a short period of wear during the Spring produced fading which was V-shaped owing to the fact that a coat had been worn. On the other hand the author had some green casement fabric, which received about five years practically continuous exposure at a clear unshaded window facing S.S.E. The fabric then had begun to tear owing to sunlight tendering ; but only very careful inspection revealed the fact that some slight fading had taken place.

The fastness of dyeings to sunlight is sometimes very considerably affected by after-treatments. The author on one occasion tested a number of Sulphur dyeings (Thionone dyes) on pure silk. They were not very fast to light, but after a boil in a weak solution of copper sulphate (coppering) the colours were remarkably fast. The actual gradings were :

TABLE NO. 12

Light fastness of Sulphur dyeings on pure silk.

Colour.	Yellow.	Indigo.	Sky Blue.	Green.	Claret.	Brown.	Black.
Normal dyeing	Turns brownish	Not fast	5	Not fast	Not fast	2–3	5
After coppering	1	1	2–1	1	2	1	1

Many people believe that certain colours are always fugitive to light. This is not a fact, for the stability of a dyestuff to light is a question of its chemical structure and not of its colour. Probably the belief arises from the experience of previous decades. For instance, mauve is generally supposed always to be fugitive (though the author has not found this so), and it may be that this belief dates from Perkins' mauveine, which was not a fast dye.

The colour that is most often fugitive is bright blue, though this can be obtained of excellent fastness. Red and yellow are generally of fair fastness to light. In compound shades produced by using several dyes, colour change may occur owing to one dye fading more rapidly than the others. Green is a colour frequently found to be fugitive, maybe due to the use of a fugitive blue.

Arising out of this discussion of light fastness, mention must be made of the unfortunate property possessed by some vat dyes. When exposed to light a photo-chemical action occurs and hydrogen peroxide is produced. This may bleach some colours which are fast to light ; and cellulose fibres are tendered by oxidation. The dyes are of yellow, orange and red colours, but not all vat dyes of these colours suffer from this defect. In one complaint investigated, a print cotton-rayon window fabric had torn badly in the first wash after six months use. The white rayon weft was very severely tendered in the areas where the warp was printed yellow or orange-red, but elsewhere it was of normal strength. When a warp thread was removed and tested its breaking strains on a yellow portion was 7.9 ozs., while on other portions the breaking strain was 12.8 ozs. Another complaint

was a " fadeless " jaspé taffeta. In one portion, the blue threads had faded very seriously and the fabric had torn after one year of use. The fading of the blue colour was due to bleaching from the action of the orange-red weft threads under the influence of light. Tests showed the orange red threads had lost 38% of their strength in this region. Moreover, the loss in strength increased to 65% when the threads were boiled in weak caustic soda. This is characteristic of oxidised cellulose (see p. 36).

There are over 300 vat dyes known. The few that have this unpleasant property should be placed in an Index Expurgatorius together with certain other dyes which are too fugitive in properties for modern needs.

Closely connected with light fading in some conditions of exposure is *Weathering*, that is the effects of rain and air oxidation. Colours are tested for susceptibility to weathering by immersion in solutions of hydrogen peroxide. The effects may either be a bleaching or a change, which is usually a darkening or dulling of the colour.

When *Mildew* grows on a fabric it is quite probable that it will produce changes in the colour of the dyestuff. It is almost sure to affect the dyeing properties of the fabric should it be re-dyed.

Some colours are affected by *Street-mud*. This is very objectionable in dress fabrics, suitings, and coatings, which inevitably get splashed occasionally or frequently. The test used is to place a small piece of paste, made of slaked lime and water, on the fabric, and to let it dry, and then to brush off the powder. A change of colour under these conditions means risk of staining by street-mud.

Perspiration is a liquid of a very complicated

composition, and one which may become still more complicated by its decompositions. It is stated quite commonly that some people have perspiration which is unusally active in affecting fabrics and colours. This may be so, but if such cases exist they are probably very rare. In the laboratory two simple tests are applied for colour fastness to perspiration and they have proved sufficient to account for the phenomena in every complaint against colour fastness due to perspiration which the author has investigated. The first is immersion of the fabric backed with some white fabric in a solution of acetic acid and common salt at body temperature. Note is made of colour change, extraction, and bleeding on to the white material. A bad example was the case of a print crêpe de chine, where on test the white fabric received nearly a perfect reproduction of the original print. This material constituted part of a frock, and the lady complained that the pattern clearly reproduced itself on her arm and could not be removed by washing; from the tests (see Fig. 45) it is clear this could happen. At other times in this perspiration test there may be a change of colour due to the acid. In the second test the sensitivity of the colour to ammonia is concerned. Such effects occur owing to the decomposition of perspiration. A blue velvet frock was returned with greyish white patches under the arms, along the fore-part of the sleeves and on the back. These were due to the action of ammonia (from decomposed perspiration) on the dye, which was alkali-sensitive. The colour was restored by treatment with acid.

Many of the basic dyes, which will most frequently be met on silks, are soluble in *Alcohol*. In con-

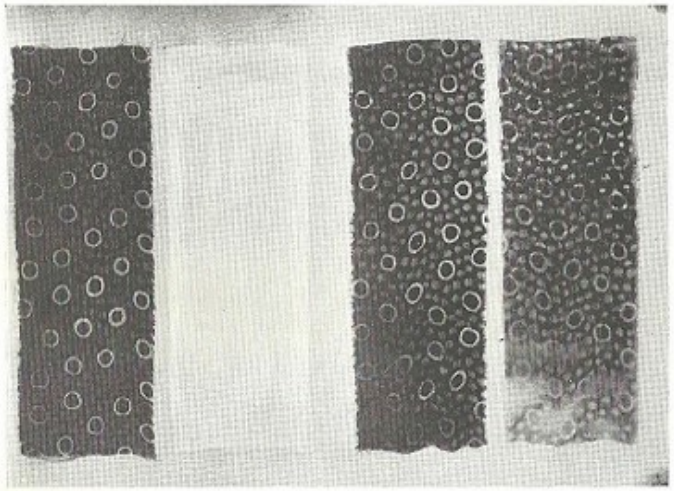

Fig. 45.—A perspiration test on a print crêpe de chine. On the left is a strip of the fabric and a piece of the white silk which was used to back it in the test. On the right is the fabric after the test, followed by the piece of silk which was originally white.

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sequence perfumes, or other alcoholic liquids, may extract colour, leaving an unsightly patch or staining any fabrics underneath. As ladies' silk handkerchiefs are very likely to be exposed to treatment with perfume, it is advisable with these to perform a simple test for fastness to alcohol.

On occasion vat-dyed and normally "fadeless" fabrics have faded, and investigation has shewn this to be due to traces of *Chemical Fumes* in the air. This is an unusual state of affairs and cannot be considered in the ordinary testing of fabrics for colour-fastness. But provided the nature of the fumes are known it is, of course, possible to test dyed fabrics and to discover some that are fast to the fumes concerned. A much more frequent cause of disappointment, and sometimes of complaint, arises from the *Fumigation* of rooms after an infectious illness. The usual process of fumigation is to burn sulphur in the room. This produces sulphur dioxide, a gas which possesses very strong bleaching properties. Here again is a factor that cannot be considered in the normal testing for colour-fastness.

Arising out of the previous paragraph there is one point of practical importance. Wool is usually bleached with sulphur dioxide, and it retains traces of the gas for a long time. If such fabrics are coloured with a dye sensitive to sulphur dioxide, then colour change or bleaching may occur during storage. Trouble due to this cause has occurred owing to the bleaching of coloured ribbon used as binding around the edges of white woollen blankets.

Some dyes are sensitive to weak *Acid*, a colour-change occurring. Troubles due to weak acid do not occur often in normal use. The more frequent

trouble is concerned with the strong sulphuric acid from accumulators. This acid will destroy most fabrics and affect many colours. It does not damage wool, and so if spots of discolouration, due to strong acid, occur on wool fabrics it is advisable to try the effect of treatment with ammonia. This will restore the original colour in many cases. Weak acid stains may be met in fabrics caused by, say, vinegar or cosmetic preparations (particularly one anti-perspiration cosmetic which consists of a very concentrated acid solution of aluminium chloride). In these cases, also, treatment with ammonia will probably restore the original colour.

Section 5

Colour-fastness Possibilities and Colour-fastness Requirements.—A familiar excuse in the case of colour failure in wear or wash is that no "fadeless" colours can be obtained. This is undoubtedly true, for a "fadeless" colour should withstand eternity. But it is begging the question, for the fabrics will not last for ever, and the requirements of the most exacting consumer are quite limited when expressed in terms of years. There are dyeings which will fade considerably after one day's exposure to light, and dyeings which will not fade much after five hundred days' exposure to sunlight. The second can be regarded as commercially "fadeless" to light. There are dyeings which are completely stripped by a boiling wash, and other dyeings which are unaffected by ten times boiling. The second class can be regarded as "fadeless" to washing.

From the consumer's and the retailer's point of view dyeings can be grouped into four broad classes. The factors which have to be considered in this classification will depend on the use for which the fabric is intended. But for illustration in the table below only light and washing have been considered.

TABLE NO. 13

Colour-fastness groups.

1. Fugitive. Distinct fading after three days' exposure to summer sunlight.
   Colour loss very distinct with ordinary wash and may not withstand even a mild wash.
2. Ordinary. Requires seven to fourteen days' exposure to summer sunlight before fading is evident.
   Colour loss very slight with ordinary wash, and none with mild wash.
3. Fast. Requires fourteen to twenty-eight days' exposure to summer sunlight before fading is evident.
   No colour loss with ordinary wash and only slight loss with hot wash.
4. Fadeless. No fading after six weeks' exposure to summer sunlight.
   No colour loss on boiling.

It is to be hoped that the "Fugitive" class will soon be eliminated, and it is also greatly to be desired that before long manufacturers and retailers will adopt the two descriptions of "Fast" and "Fadeless" for fabrics properly described under these headings.

There are about 1,500 chemically different dyestuffs known, and many more are discovered each year. These dyes vary in many ways, including that of degree of fastness to the factors discussed in the previous section. Many dyestuff manufacturers now give

data concerning the fastness of their products, but it is clear that any dyer can make experimental dyeings and then perform fastness tests. Such a research is not exceedingly costly or laborious and yet its results can ensure great satisfaction in the qualities of dyed goods. The need for such testing is quite clear. The author desired to ascertain how far it was possible to get ordinary dyeings on silk of a good all-round degree of fastness to light, washing and perspiration, and so wrote to a number of dye-makers asking for dyes they recommended for this purpose. A range of 120 dyestuffs was secured and applied to Jap silk, and then tested for fastness. Out of this range of 120 recommended ordinary dyes (direct cotton and acid dyes) it was found that 21 were of the requisite all-round fastness. These 21 satisfactory dyestuffs were from a number of different manufacturers. The degree of fastness obtained was the same as that of some brands of silk fabrics sold as "guaranteed fast." It will be realised that any dyer securing his supplies from one manufacturer could not get this degree of fastness, for some of the dyes supplied would be below standard. If he used recommended dyes without selection, then only one in six would be of good fastness. So the odds against using a satisfactory range of dyes without testing are very great.

The research referred to above served to select dyes fast on pure silk. Further test showed that on mineral weighted silk the dyeings retained their fastness to washing and perspiration, but to light they were more fugitive. On weighted silk there appears to be great difficulty in getting all-round fastness with ordinary dyes ; either the light fastness or the washing and perspiration fastness has to be sacrificed to some

extent. The change in light fastness of the satisfactory dyes is given in the table below.

TABLE NO. 14

List of ordinary dyes of good all-round fastness on pure silk, and gradings of light fastness of 2% dyeings on pure silk and mineral weighted silk (45% weighting).

Dye.	Pure.	Weighted.
Diamine Scarlet B	2	4–3
Chlorazol Fast Red FG...	2	4
Neolan Red R	2	3–4
Sulphonine Brilliant Red B Conc	1	4–3
Chlorantine Fast Red 7 BL	1	4–3
Diamine Fast Yellow B	1	3
Chrysophenine G	1	4–3
Neolan Yellow GR	3–2	3
Chloramine Fast Blue 4 GL	3–4	Not tested
Xylene Fast Blue GL	3–2	5
Chlorantine Fast Blue 4 GL	3	Not fast
Chlorazol Violet N	1	4
Chloramine Fast Orange S	1	3–4
Chlorantine Fast Orange G	2	3
Chlorantine Fast Green BL	1	4
Chloramine Fast Brown RLC	2	4–3
Chlorantine Fast Grey BLN	2	Not fast
Chlorazol Black DV	3	Not fast
Chlorazol Black SD	3	Not fast
Neolan Black B	1	5–4
Neolan Black 2R	2	Not tested

In the preceding paragraphs the endeavour has been to show that there are many different dyestuffs and that with proper selection, which does not involve great expense, a selection of any type of dyestuffs of satisfactory, or very superior fastness, can be obtained. In qualification of this it must also be stated that if some rigid standard of fastness is aimed at, then probably it may prove difficult to get a palette of colours sufficient to give a complete range of shades. In such lines it may prove at present impossible to

get certain shades. In ordinary dyeings (not vat dyeings) the most difficult colour to get of satisfactory fastness to light is a clear bright blue.

For the " fadeless " type of dyeings the main class is the vat dyes, and to some extent the mordant and the diazotized and developed dyes are useful. This means that a simple test can be applied which determines whether a fabric is not " fadeless." Take some of the fabric and sew white cotton fabric to it, and boil the two for fifteen minutes in a little soap and water. If the white cotton is stained then the colour is not " fadeless," and if there is distinct loss of colour the dyeing is equally not " fadeless." This test will serve to expose many of the furnishing fabrics which are nowadays offered as " guaranteed fadeless."

The fast or third group of dyeings can be of any type of dye. They require to be selected dyes properly dyed. They can only be verified by tests. Such tests are preferably laboratory tests, but anyone can expose fabric at a window for a week, or make a washing test, or even sew some fabric to white material and give a perspiration test by fixing it under the arm for a day.

In concluding this section a few remarks on the requirements in fastness for different fabrics may be made. The ideal, of course, would be all " fadeless " colours, but commercially there is no advantage in seeking colours on fabrics that are fast to factors to which they will not be exposed in use, for it is only likely to add to cost. On the other hand, to buy or to sell fabrics with colours that will not withstand the normal use of that fabric is foolish.

In furnishings the first requirement is clearly fastness to light. Rugs, carpets, and to some extent

furniture coverings, principally require fastness to light. But window draperies, in addition to fastness to light must have some reasonable fastness to washing as well. Tests on these fabrics should be made for fastness to light, weathering, washing and hot-ironing.

Dress fabrics and suitings should have a good fastness to light. Generally speaking, men's suitings are reasonable in this quality. In women's dress fabrics, in place of mordant dyeings are usually acid dyeings or direct cotton dyeings, and a proportion are very fugitive to light. A second requirement is fastness to perspiration, more particularly on dress fabrics.

A point of interest affecting suitings is the description " indigo dyed." It might reasonably be supposed that this means the colour is all due to indigo. But in present day practice " indigo dyed " suitings, etc., have a large proportion of their colour due to other dyes (usually fast mordant dyes), and in some cases the proportion of indigo is very low. As mordant dyes of very great fastness are available the description as " indigo dyed " has more merit as a " selling point " than as indicating the highest degree of colour-fastness in suitings.

Fabrics sold for frocks can be divided into two classes ; those for ordinary day wear and those for more special occasions such as evening wear. In both cases fastness to perspiration is desirable, though in all cases where possible dress shields should be worn. In exceptional cases fabrics may be of a type that cannot be washed, or are not intended for washing ; for instance, marocain, which often shrinks severely if washed, but can safely be dry-cleaned.

But, in general, colours on fabrics for frocks must be reasonably fast to washing And day wear fabrics must be of fair fastness to light.

In underwear colours should be tested for fastness to washing and to perspiration.

Towels, handkershiefs and table linen should be fast to washing, and in the general case the dye should be very fast, as washing to secure stain removal may be severe, or the use of "chemicals" may be necessary.

Shirtings must be fast to light, as the cuffs and V-neck portions get considerable exposure, and very fast to washing, as they frequently get a very hot or boiling wash, and they should also be fast to chlorine, or, as already stated, trouble may occur in laundering.

CHAPTER V

WASHING, LAUNDERING AND DRY-CLEANING

Section 1

General Facts Concerning Washing Processes.—During their existence most items of textile merchandise require cleaning a few or many times. The nature of the cleaning processes can very considerably affect the useful life of the textiles concerned. It is, therefore, well worth while to discuss the matter in a detailed manner.

The first item for consideration is the water. Everyone knows from experience that hard water will only give a lather with soap after some difficulty, and when some curd has been formed. This curd consists of compounds formed by interaction between the soap and the "hardness" of the water. The hardness of the water is mainly due to lime salts in solution. Now soap consists of a compound of soda or potash and the main constituent of a fat, that is the fatty acid. The curd consists of a compound of lime and the fatty acid. These compounds will be referred to as lime soaps.

When soap is added to water, the first thing that happens is that the hardness reacts with it and forms insoluble lime soap. This means a wastage of soap, for lime soap is valueless. There is, however, a more serious aspect. In washing, these lime soaps are part of the dirt, and are held in suspension by the rest of

the soap. But when the soapy fabrics are rinsed in hard water these lime soaps are formed on and in the fabric, and are only partially removed by the rinsing. These lime soaps are soiled (as they come from the wash-tub) and they discolour the fabric. Moreover, they form a film that is of a somewhat sticky nature, and so fabrics with lime soaps in them soil more readily. In hot-ironing, the lime soaps melt and penetrate the fabric more deeply, so increasing the trouble, and if low grade soaps are used, they may also become yellowish, or be odorous.

When fabrics are washed without special care, and with hard water, they will become more and more discoloured, and finally they will return from each wash a very grey colour. With vigorous hot washing and particularly with a good boiling wash, lime soaps may be largely removed during each wash, and so though the goods will never be of good colour they will not become very grey.

It is clear, therefore, that in washing the first desideratum is soft water. Rain-water, or water treated in special chemical softeners, is not always obtainable. Fortunately, however, a sufficient degree of softening is easily secured by the use of washing soda. If a little washing soda solution is added to hot tap water, then in a short time a cloudiness will develop, for the lime is precipitated as an insoluble carbonate. In this state it cannot react to form lime soap when the soap is added. For water of ordinary degree of hardness half an ounce of washing soda should be added to each five gallons of water; very hard water may require double the amount, and fairly soft water may require much less. For approximate measurement the capacity of an ordinary large bucket

may be taken as two gallons and a tablespoonful of washing soda crystals will weigh about one ounce.

Soaps vary considerably in their washing power according to the fatty materials from which they are made. Oil soaps are those made from oils (or fats of low melting point) and they have a good degree of solubility and cleansing power in cold or warm water. Hard soaps are those made from fats of higher melting point, such as hard tallow, and they are less soluble, and have less cleansing power, than oil soaps in cold water, but in hot water or at the boil they are much superior. For cold or tepid washing, coconut oil soaps are the best; for ordinary washing, olive oil soaps or vegetable oil soaps (Castile soaps) are desirable; while hard tallow soaps are only suitable for hot washing and boiling.

Soiled fabrics contain matter removable by solution in water (such as perspiration and some stains), and greasy matter, and dirt, and maybe colouring matters such as those from tea, coffee, or wine. Soap possesess the property of attacking greasy matter, whereby it becomes wetted and then breaks up into particles, which are held in suspension. Equally the particles of dirt become wetted, and then small agitation removes them from the fabric and the soap holds them in suspension. It has been found that soda has these wetting out and emulsifying properties to a small degree, but when present with soap the combined washing power is improved. There is a point beyond which the strength of the soda, or the soap, in the wash liquor gives no advantage, and as the use of extra soda and soap increases expense it is clear that in ordinary washing some reasonable care in

measuring the amounts of water, soda, and soap used is advantageous.

The final process in washing is rinsing. When clothes are removed from the tub they contain a considerable amount of dirty wash liquor. Suppose the rinse water is nine times the volume of wash liquor so carried over, then one rinse will mean that nine-tenths of the dirty soap liquor is removed, but two rinses using fresh water each time will mean ninety-nine-hundredths are removed and three rinses nine hundred and ninety-nine-thousandths. The essential to good washing is good rinsing ; at least two rinses in plenty of water, and preferably three rinses, are desirable.

One general point affecting washing is concerned with the dressing on new fabrics. This dressing may include calcium and magnesium salts, and so if the fabrics are immersed directly into soap solution insoluble metallic soaps will be formed in the fabric. If the fabric is rubbed over with a piece of soap, these metallic soaps may form small greasy lumps tenaciously bound to the material. Before new fabrics are washed they should always be soaked in warm water, and then well rinsed to remove any soluble dressing. Any insoluble dressing will be removed by the washing process. This treatment is most important with cotton fabrics.

Section 2

Details of Washing Processes.—Now the ordinary domestic washing process can be considered, first dealing with white cotton goods, and subsequently mentioning modifications necessary for coloured goods, wool, silk and rayon.

The first process is soaking. This loosens a large

proportion of dirt without much labour, and also dissolves albuminous matters exuded from the body. These latter would become fixed if immersed in hot water, as is well demonstrated with blood stains ; which if hot washed leave a permanent brown stain, but if first soaked in cold water are completely removed.

For soaking, first dissolve two ounces of soda in a jug of warm water and add to five gallons of water, which can be cold, or preferably, tepid. After two or three minutes add two and a half ounces of bar soap, or just over two ounces of soap-flakes, dissolved in a little hot water. Now immerse the clothes and see they are thoroughly wetted. Leave for two hours or more (preferably over-night) and then agitate for a brief time by hand, vacuum washer, or other device, to remove all the loosened dirt into suspension, and then wring the clothes.

The goods are now ready for the hot wash. The solution is prepared as above except that the water used is hot. If the goods are greasy double the amount of soap and soda is used. The soda must be added first so that the water is softened. Suitable agitation or rubbing is given, but the soaking has removed a large proportion of the dirt and rendered the residue very loose, and the labour required for efficient washing is, therefore, considerably decreased. Experiment in shortening the process and observing results will show the minimum necessary for efficient washing. When a boiling wash is required in addition only half the quantities of soda and soap given above are to be used in this process.

The first rinsings should be with softened water ; the last may be with ordinary water. Before

entering into the rinsing water the clothes must be wrung to remove as much of the soap solution as possible. There should be at least two rinses and preferably three, the clothes being wrung out between each rinse. The blueing, if any, should be given with the last rinse.

When coloured goods are washed for the first time care is necessary. They should not be washed with other coloured goods lest the dye be extracted and discolour them. If the item has been made at home the cautious housewife will always test the washing properties of a small piece cut from the cloth. With guaranteed fast colours it may be found that on the first wash the soap solution is somewhat discoloured, but this is only loose surface dye that has no staining properties, and after the first wash no trouble is experienced. For the soaking and the washing (which should be in lukewarm water only) water softened by soda should be used, but no extra soda should be added. With loose dyes the addition of common salt to the water will help to prevent running. But where the colours are so loose as to require this, the merchandise is certainly very defective. The rinsing water should be tepid or cold. Only colours " guaranteed fast to washing " should be expected to withstand the ordinary white cotton goods wash. Goods " fadeless " to light may not be " fadeless " to washing.

Wool has two special properties which affect the washing process. The first is its felting or shrinking, and this has already been discussed (Chapter III, Section 8). The second property is its power to absorb alkali. Soap is a compound of fatty acid and alkali. Wool placed in a soap solution absorbs some alkali, leaving some free fatty acid which

may settle on the wool. When wool is immersed in a soap solution it may affect so much soap that a lather is not obtained. But if some washing soda or ammonia is present, then this prevents the destruction of soap, as it provides alkali which the wool can absorb. For this reason it is desirable to have some washing soda or ammonia present in the wash liquor, and also to give at least the first rinse with water containing some soda or, preferably, ammonia.

Some of the alkali absorbed by wool is fixed so strongly that even after prolonged rinsing, washed woollens have a faint alkaline reaction. As new wools often have a slightly acid reaction, this gives a simple test that can be applied (provided original fabric is available) when it is stated that a woollen fabric or garment has not been washed.

The washing process for woollens is as follows : Dissolve one half tablespoonful of soda in each bucketful of water. Use this for making the soap solution, which should only be lukewarm. Immerse the articles (preferably after a preliminary soaking in cold water for a short time and then squeezing out) and work about gently in the soap suds with no rubbing and only gentle squeezing. This will generally give efficient cleansing, but if any portions do require more severe treatment, let the rubbing be as gentle as possible. When clean give two separate rinses in lukewarm water softened by soda, and then one in cold water. In place of soda ammonia can be used ; sufficient to give a distinct but not strong smell will be enough.

Woollens washed in this manner will be found to be much more pleasing than those washed in soap alone. With ordinary soap washing some fatty acids are inevitably left on the fibres. Sometimes manu-

facturers of woollen underwear will reply to complaints of shrinkage by stating that excessive soap has been left in the fabric. This is not a very convincing excuse, as it will be realised that in at least nine cases out of ten fatty acids could be extracted from ordinary washed woollens.

A process of washing woollens in very hot water is sometimes advocated. The advantage of such washing, followed by a hot rinse, is that any free fatty acids are melted in the hot water, and so do not adhere to the fibres. If rubbing is avoided, hot washing is quite safe, but the process already given is the preferable one. There is less risk of shrinkage.

While dealing with this subject some reference must be made to a unique process advocated for the washing of woollen underwear. This process consists first in soaking the woollens in dilute hydrochloric acid and then washing in dilute ammonia. With woollens that have been wrongly washed this process is useful on occasion, but it is not suitable for general use. When fabrics have lime soap fixed on the fibres, owing to the use of hard water, they may become unpleasant. Treatment in dilute acid dissolves the mineral matter and so leaves only the fatty acid of the lime soap in the fabric. The subsequent treatment with ammonia dissolves the fatty acid, giving an ammonia soap, and this soap helps to cleanse the fabric. But once done, it should not be required again if the fabric is washed properly thereafter.

Silk and rayon (artificial silk) are both fibres which are very smooth and so require very little treatment to remove the dirt. Washing should be done with softened water and soap only, and with rinsing in softened water. Movement about and swirling in the

solution should be all that is necessary ; rubbing is not required. The water in washing and rinsing should only be tepid. With rayon special care is necessary during washing as the material usually loses about half its strength when wet (sometimes more), though it regains all its strength when dry. Damage may easily be caused by buttons, clasps, or by wringing.

With spun silk or rayon the material will not shed its dirt so easily as with nett yarns, but slightly longer processing is all that is required. Note that spun silks may be considerably weakened while wet. For instance, tests showed that schappe silk when wet had only 55% of its strength when air-dry.

The fine lustre of silk fabrics is improved in manufacture by a process known as " scrooping." The fabrics are left for a short time in a weak acid solution, and then wrung out and dried without rinsing. After washing silks, the lustre can be improved by a process of scrooping, using either strong acetic acid or vinegar. With strong (glacial) acetic acid add half a teaspoonful to a quart of water, or with vinegar add two tablespoonsful to the quart. Immerse the washed and rinsed silks in this solution and leave in for five minutes, then take out, wring and dry. A further advantage secured by this weak acid finishing operation is that where acid dyes have been used on silk and loosened by the washing, the acid will help refix them, and in case of alkali sensitive colours the acid will restore the original colour. If the colour of a fabric is alkali sensitive and seriously affected, it may be necessary to leave the fabric in the weak acid for half an hour or an hour before the colour is completely restored. Before washing silks for the first time they should be soaked in tepid water and then rinsed.

This removes any acid due to scrooping. Should they have been scrooped after washing, this soaking is necessary each time. If it is not done, the fabric may get contaminated with fatty acids from soap decomposed by the acid. Complaints due to such causes have occurred. In such cases the fatty acid has been removed by rinsing in very dilute tepid ammonia solution.

After washing goods should not be left about wet. This entails risk of damage by micro-organisms, and with coloured goods there is the risk of colours bleeding or marking off. These points have already been discussed on pages 52-55 and 100. Moreover, coloured goods are preferably dried in the shade, for the presence of water accelerates sunlight fading. In drying stockinette garments, they should be first pulled into shape and then dried flat, or severe deformation is probable (see page 71). With coloured goods it is best to ensure that cloth is not in contact with cloth during the drying or printing off may occur. If necessary it is usually possible to fix towels or paper between the portions of cloth.

Various points concerning hot-ironing have already been considered. There will be some recapitulation and a more extended survey of the subject.

Shrinkage is least when cloths are ironed while evenly damp. In consequence, collars and the neck-bands of shirts are preferably ironed when very damp and until they are dry. White and fast-colour goods are best brought in before they are completely dried and left loosely piled together for an hour or so, which will ensure an even degree of damping. If such goods are dried completely they should be sprinkled with water and then loosely rolled up and

left for several hours. With coloured goods of ordinary fastness it is best to iron before they have dried completely; if any damping has to be done it can be effected on the ironing board by rubbing with a damp cloth. If non-woollen fabrics are seriously shrunken after washing and normal ironing, it is worth while to dip them in water, squeeze as dry as possible and then iron till dry; this may reduce or overcome the shrinkage.

A fact of interest is that an over-heated iron will more easily scorch a piece of wet cotton cloth than a piece of dry cloth. So if cotton goods are sprinkled with water and then rapidly smoothed with an over-heated iron, scorching may only occur in patches.

Coloured fabrics may print off on to other fabrics, so never iron one portion in contact with another if it can be avoided. If it must be done use a cool iron. Some colours are also changed by hot-ironing and the hotter the iron the greater the risk. So on coloured goods never use an iron hotter than is necessary to give good smoothing.

A hot iron will melt acetate rayon or give glazed patches, and it will turn silk yellow.

The following table issued by the National Association of Cotton Manufacturers (U.S.A.) is of interest:

TABLE NO. 15

Time of contact to scorching and temperature of hot iron.

Material.	Time of Contact, in Seconds.		
	One.	Two.	Three.
Cotton . .	510° F.	487° F.	442° F.
Viscose rayon .	463° F.	—	375° F
Linen . .	447° F.	425° F.	403° F.
Unweighted silk .	447° F.	425° F.	403° F.
Wool . .	397° F.	375° F.	350° F.

The recommended limits of temperature for use under power laundry conditions are :

Wool and acetate rayon . .	340°-400° F.
Cotton, linen, cellulose rayon and washing silks . . .	435°-495° F.

It is stated [1] that Celanese becomes sticky or melted at 400° F., so for acetate rayon the recommendation is close to the danger limit. For home use, only a moderately warm iron is advisable. The above table shows that if a hot iron is used it is best tested first on white cotton, and if it causes a scorch in five seconds contact, it is dangerously hot.

Note that silk is scorched at a much lower temperature than cotton. The author has investigated complaints alleged to be due to perished silk which in fact have been due to tendering owing to smoothing with an over-heated iron. Weighted silk is more susceptible to heat tendering than pure silk.

Section 3

Stain Removal.—Washing cannot be discussed without some reference to stains. The important matter is to treat them promptly, first with water and then with soap. Many of them, such as red ink, fruit, tea, coffee, wine, etc., can be regarded as dyes ; at first they are only loosely attached to the fibres, but with age they combine more firmly. Cold water should be used first. As already mentioned, blood-stains are almost completely removed by cold water, but in hot water the albumen of the blood is coagulated (like the white of an egg) and the stains are then practically irremovable.

[1] *The Control of Laundry Operations.* Parker. p. 184. Published by the British Launderers' Research Association, 1925.

Red ink stains may be removed by treating the affected portion with ammonia solution. If complete removal does not easily occur, leaving the fabric soaking in weak ammonia solution for several hours or overnight will usually remove the stain, and in the majority of cases this mild treatment will not affect coloured fabrics.

Many stains are removed by a vigorous hand washing, or, with white goods, by a boiling wash.

Sometimes there are obstinate stains, or ingrained dirt, or a mixture of oil or grease and dirt. Frequently good cleaning can be secured in a case of this type by wetting out the patch in water, then rubbing in soft soap and leaving for a time (say at least half an hour) and then washing. Soap in strong solution can remove even oil or grease. A better method still is to rub in a soft fatty acid (the fatty constituent of soap) and then after a time wash out in ammonia. Oleine (oleic acid) is the most suitable fatty acid to use. In this way the fatty acid dissolves the grease and then the ammonia combines with the fatty acid, forming a soap right in the stained yarns.

Paint stains can be treated with turpentine. This will dissolve away the medium and leave only the pigment, which may drop away or be removed by brushing. Old paint stains may require some soaking in turpentine before they are removable. Grass stains, and also those from blue carbon paper (which is frequently a cause of accidental staining of goods while in the shop), may be removed by treatment with methylated spirit. Ordinary grease stains are removed by petrol or benzine.

When using solvents on fabrics special care is necessary or ring-marks occur round the stain, and

they cannot be removed except by completely immersing the article. The following technique will avoid such ring-marks with clean fabrics. First place under the stained fabric a pad of blotting-paper or cotton wool, and then pour some solvent into a convenient receptacle which is placed near at hand. Dip a small pad of cotton wool or absorbent cloth into the solvent and while it is still wet make a circle round the stain and at least two inches from the stain, and then at once continue the circular movement, working in a spiral to the central point, which is the stain. Repeat the process if necessary.

After solvent treatment any slight stain still present may prove to be removable by a local washing operation.

If stains resist all these treatments they should be submitted to a laundry or cleaning firm, stating, if possible, the cause of the stain. The use of chemical stain removers usually involves great risk to the fabric, and with coloured fabric colour may be removed as well as the stain. It will be found that laundries and cleaners will usually only undertake stain removal at the owner's risk, as sometimes it is impossible to avoid damage.

Section 4

Laundry Operations.—Good or bad laundry practice is a matter of great importance, for it affects the wear and satisfaction secured from the textile merchandise. At present troubles arising during or after laundering are too frequently immediately attributed by the distributor or consumer to bad laundering, and by the launderer to defective merchandise.

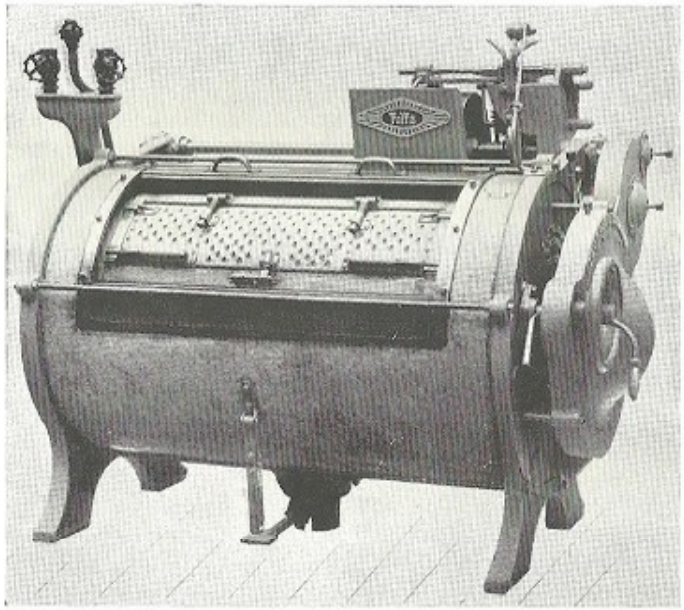

Fig. 46.—A laundry "wash-wheel."

(Courtesy of D. J. Tullis & Co., London.)

[*To face page* 131.

The goods received at the laundry are first sorted into a number of groups so that similar articles can receive the appropriate laundering treatment. The white cotton goods wash will be considered first. The initial washing operation is the preliminary soak. The goods are placed in a washing machine and agitated with water for about ten minutes. The usual "wash wheel" (see Fig. 46) consists of a large drum with a lid forming one top segment, and containing inside a cylindrical perforated cage which is mechanically revolved on a horizontal axis, the direction of revolution being reversed after about three rotations. Inside this cage are ledges (called lifters) which protrude sufficiently to lift the items being washed for a part of the revolution, when they fall back into the bottom of the cage. The tumbling about of both liquid and fabrics in the wash wheel provides the agitation necessary to secure the washing. The preliminary soak serves to loosen dirt, but mainly to remove soluble matter and the coarser particles of dirt which would use up much soap. The water is then drained off, and the soap and soda solution and hot water are added and the hot wash is given (the temperature being regulated by steam heating). This usually takes about 15–20 minutes, and then the dirty soap liquor is run off and the boil is given, followed by the rinses, which are usually more thorough than those of the average domestic wash.

As this process may not suffice to secure whiteness on stained goods, an additional process of mild bleaching is required in some cases. This may be done during washing, bleach being added to the soap solution during the hot wash, or it may be conducted as a separate operation. For serious stains a separate

stain removing treatment may be necessary, when they are "spotted" with various chemicals. This requires great experience and skill if it is to be done effectively and without damage to the fabric.

After rinsing, the goods are freed from much of the water in a "hydro-extractor." This is shown in Fig. 47. It is a cylindrical cage with perforated sides which can be spun at a high rate about its vertical axis. The centrifugal force throws out the water and packs the clothes against the side of the cage.

Items such as table napkins, table-cloths and sheets are dried and smoothed by calendering. A calender (shown in Fig. 48) consists of one or more rollers (long, heavy metallic cylinders, coated with felt and sheeting) revolving in semi-circular beds; the cylinders and the beds are both steam heated. Other goods (such as frocks and shirts) require hand treatment in smoothing, and this is done by hot-ironing. For partial or complete drying, the goods may be hung or racked in a drying chamber, either heated with radiators or with a circulation of hot air, or, more recently, drying has been effected in a revolving drum with hot air passing through. The finished goods may be hung in a hot room for a final "airing."

Coloured goods are usually sorted into a fast-colour group and an ordinary group. Ordinary goods are given a careful wash at low temperature and, if necessary, by hand. The fast-colour goods may receive the equivalent of a hot wash. Woollen goods are either hand-washed or treated at a low temperature in a wash wheel which revolves at a much lower rate than usual, so reducing the friction to the minimum. Silk, rayon and expensive or delicate goods are hand-washed and finished.

Fig. 47.—A hydro-extractor.

(Courtesy of Sellers & Co. (Huddersfield), Ltd.)

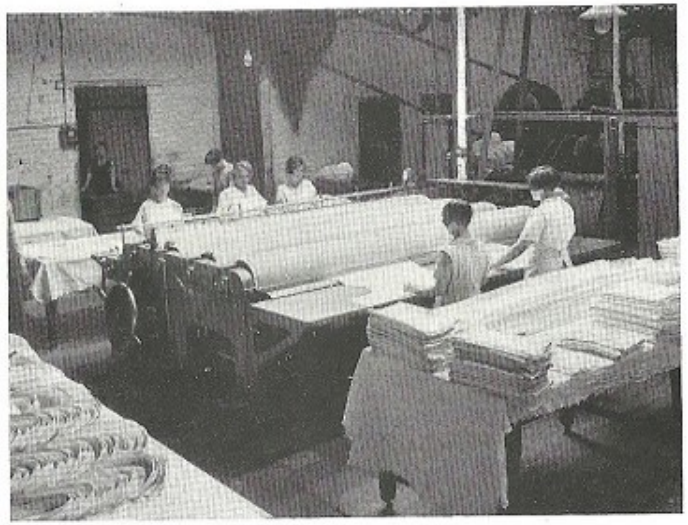

Fig. 48.—A laundry calender.

(Courtesy of D. J. Tullis & Co., London.)

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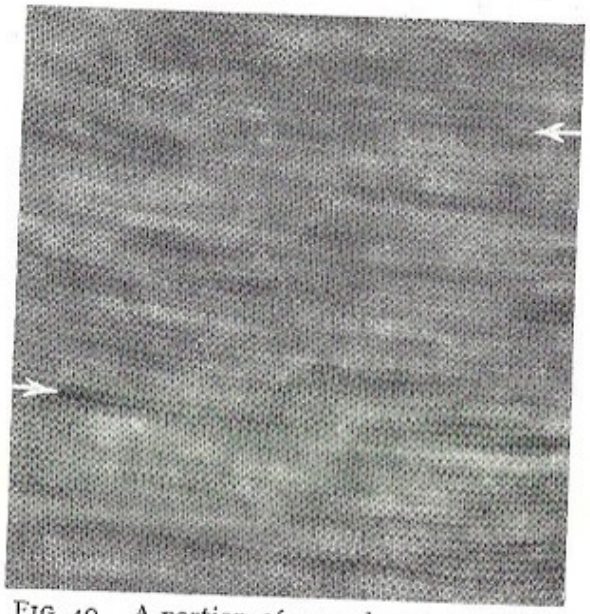

FIG. 49. A portion of a wool vest containing weak places due to thin portions in defective yarns. These weak places will soon develop into holes in laundering.

Fig. 50.—The cockling of this table-napkin after laundering is due to shrinkage of threads forming the two sides of the decorative border. This is due to uneven tension of the warp threads in the loom. (*See page* 134.)

[*To face page* 133.

The launderer has his problems and troubles and it is only fair that they should be adequately set forth.

When a fabric is wet it is usually weakened, and in any case its weight is greatly increased; bursts and tears in tendered fabrics are, therefore, most likely to occur in laundering. For instance casement fabrics and net curtains are examples where use means little strain, and normal wear effects will show in laundering. With net curtains the fabric is of very open structure and of very light weight, and so it is of course not strong. In consequence the effects of sunlight tendering soon reduces the strength so much that tears may occur in normal washing and finishing. Laundries nowadays will only clean net curtains at owner's risk. Loose colour is, of course, a great trouble, as one article with loose colour may stain many other articles.

Manufacturing defects may show up in laundering. Poor yarns mean breakages in weaving, and so are the cause of many knotted places in the fabric. A good knot is exposed to more wear than the rest of the cloth and will ultimately break, and the small hole formed inevitably enlarges with each laundering. A large, badly tied knot will break down much more rapidly. The development of many small holes in fabrics in continued laundering is frequently due to this cause. Holes that develop in warp-knit stockinette are due to breakages of the yarn, and probably many of the breakages occur where the yarn has been knotted; the holes are most likely to develop during washing.

If yarns are unevenly spun they may contain thin portions. This means weakness in the fabric, and more especially in knit fabrics than in woven fabrics, for here there is no reinforcement by other threads. The

illustration (Fig. 49) shows a number of very thin places in a new wool vest. These are due to thin places in the yarn. After ten ordinary launderings a similar vest developed four holes, due to breakage at weak portions in the yarn.

Excessive filling, or special finish on fabrics, naturally means they return from laundering thinner, or with the fine handle, lustre, etc., largely removed. Overbleached cloth may under certain circumstances lose much of its strength as soon as it is treated in alkaline liquor or washed (see page 36) ; so a fabric may be strong when sent to the laundry and weak on its return, even after nothing more than a soap and water hot wash.

Overbleached cloth is also less resistant to wear and laundering and so has a short life ; but the customer frequently attributes this, not to the cloth, but to the laundry.

In fabrics woven with uneven yarn tensions the cloth may be square when sold (owing to pulling out, etc., in finishing), but on the first wash edges may become irregular, shrinkage may occur, or the cloth may cockle. This and the shrinkage of stretched cloth (see Chapter III, Section 7) is outside the launderer's control.

The illustrations in Figs. 50, 51 and 52 show cockling and deformation of fabrics due to this cause.

Often the taut threads are in or near the selvedge, probably owing to the use of different yarns, or differing tension in the selvedge yarns during weaving. The taut threads break in laundering, and so produce weak and thin places which develop into holes on further laundering. Launderers call this " selvedge trouble," and it appears to be somewhat more frequent

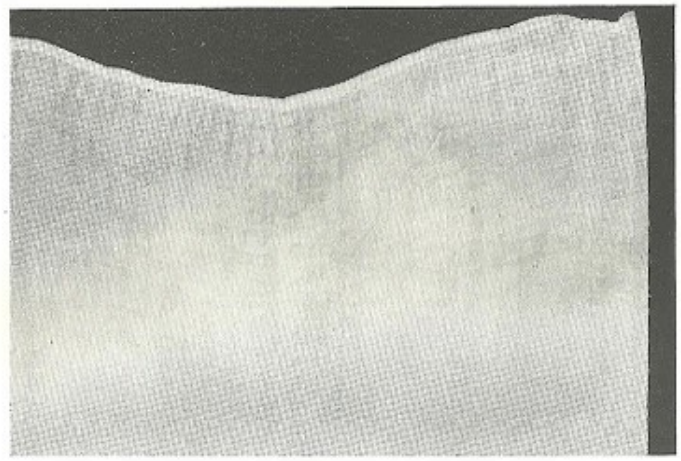

Fig. 51.—The irregular edge of this table-cloth after laundering is due to uneven tensions in the threads during manufacture.

(Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

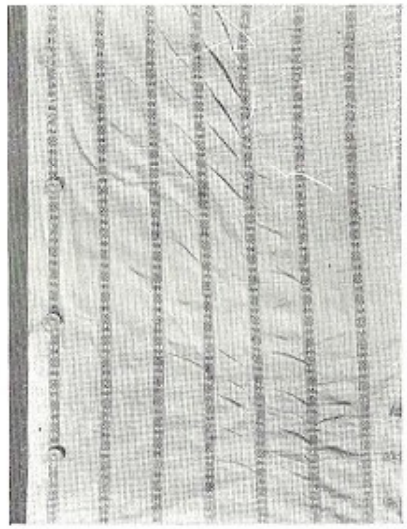

Fig. 52.—The shrinkage of the rayon warp stripes in this shirting caused the adjacent fabric to pucker.

(Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

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in linen goods than cotton goods. All cases of "selvedge trouble" are not due to taut threads, for some prove to be due to the edges of the fabric curling over, and the material then becomes crushed in laundering; here the fault is at least in part due to lack of care in laundering.

With reference to wavy ends and patterns on table linen, a recent research[1] has shewn that, in some cases, the fault is not due to taut threads, but to deformation occurring in calendering. The usual laundry practice is to pass the goods through the calender hems first. It was found that by passing them through selvedge first, the distortion of the cloth and pattern was decreased or prevented, and the goods had an increased life in laundering.

In use damage may be done which only shows up in laundering. Cuts on table-cloths may not be right through, and not noticeable until laundered. Razors wiped on towels often cause cuts. Amateur stain removal may seriously weaken the cloth and cause holes in laundering. Damage may be done by acid from accumulators, tincture of iodine, hydrogen peroxide, or the action of some cosmetic preparations (such as depilatories and acid containing anti-perspiration compounds), and this damage may only become obvious after the fabric is washed.

The launderers' case having been expressed, it is fitting that the damage the laundry can do to good merchandise should receive consideration.

Undoubtedly the most common trouble is due to careless, or inexpert, bleaching or stain removal. Improper use of bleach may cause general tendering

[1] Matthews. *Journal of the Textile Institute*, 1930. Vol. 21, p. T453.

of the whole fabric. Careless stain removal may remove the stain only by severely tendering the cloth, so causing holes to develop.

The trouble with the use of hypochlorite bleach is that it is so very effective in whitening goods that the laundry operative or the laundry management is greatly tempted to use more than is safe in order to secure rapid laundering of good appearance. The use of bleach in laundering must be most carefully controlled or serious damage occurs to the laundered goods.

It is not fair, however, to imply that the use of bleach is wrong, for the laundering to a good degree of whiteness of stained goods would be difficult without it, and the extra washing and rubbing required would cause serious wear. The British Launderers' Research Association has proved that bleach, properly used, has practically no ill effect on white cotton or linen fabrics. In the case of very serious stains the removal may be impossible without drastic treatment, which may inevitably mean some tendering of the fabric. Bleach can be regarded as nearly always necessary for table-linen and collars, and may be necessary for handkerchiefs and shirts. Colours on these goods should, therefore, in fairness to the launderer, be fast to bleaching.

Mechanical defects in laundry apparatus may easily cause bursts or tears, and severe damage will happen to any fabrics that get between the cage and the frame of the wash-wheel. Rarer faults are hydro-extractor bursts. If, owing to imperfect packing of the hydro-extractor, any portion of the cloth has pressure without support from other cloth or the side of the cage, then bursts may occur. Tears or bursts due to these various

causes differ from chemical or heat damage, in that the cloth around the damaged area is practically of normal strength.

Damage may also occur during processes involving heat treatment such as calendering, hot-ironing and possibly hot-air drying. The temperature of calenders is often as high as 330°F., and if cotton or linen is left exposed for long to such temperatures, then tendering may occur even though no scorch is visible. In a case of marking-off of the coloured border of a towel investigated by the author, the loops of the towel were found to be heat damaged. Where gas or electrically heated irons are used they may easily get overheated, or left too long in contact with the cloth while the operatives are exchanging interesting gossip. Launderers have an advantage, however, for scorched articles can be bleached to remove the scorch marks; the actual damage is not thereby removed, and in fact it may be increased.

Acetate rayon is quickly melted if smoothed by an over-heated iron. The laundry returning rayon garments damaged in this way is at fault.

No one can possibly sort fast and non-fast coloured goods by appearance without occasional mistakes. Occasionally, therefore, loose colours bleed and affect other goods. Sometimes the laundry asserts that these other goods are defective instead of admitting the fault in sorting.

Some fast colours are likely to transfer when hot-ironed. If in the laundry coloured parts are ironed in contact with white parts, then stains that cannot be removed may occur. This case is a border-line one, for certainly the dyeing is in part at fault. But the laundry staff should know that it is not safe in all cases

to iron or calender coloured cloth against other cloth, so the blame is more with the laundry. Another defect that may occur with fast-dyed goods such as bordered table-cloths, towels, etc., is that of marking off in the wash (see page 100). Finally, if coloured goods are included in the white cotton goods wash, some of the white goods may be stained. They may not come back stained, but the removal of the stain may have tendered the cloth.

Damage is sometimes due to ignorance or carelessness. The case has already been mentioned of a laundry which had to clean Jap silk uniform dresses, and used bleach, and so rapidly ruined the fabric. This may have been ignorance, or careless sorting. Another example, already mentioned, was a pair of wool and rayon combinations which were returned from laundering, now only a rayon garment with a very few small particles of yellow wool remaining; here the goods had doubtless, by carelessness, got into the cotton boil. Excessive shrinkage of woollen goods in laundering is usually due to an accident, or carelessness in sorting; the goods receive a cotton wash instead of a woollen wash.

People too often judge the quality of laundering by the whiteness of the goods, and the perfection of the finish and packing, etc. Launderers, too, are likely to reflect this view. Distributors or consumers,, however, are concerned not only with the laundered appearance but also with the wear. In the preceding paragraphs the special damage the laundry can do has been discussed. But apart from these cases good and bad laundering may differ very widely in the degree of wear occurring, while both secure equally satisfactory appearance. The author has knowledge of a test at a

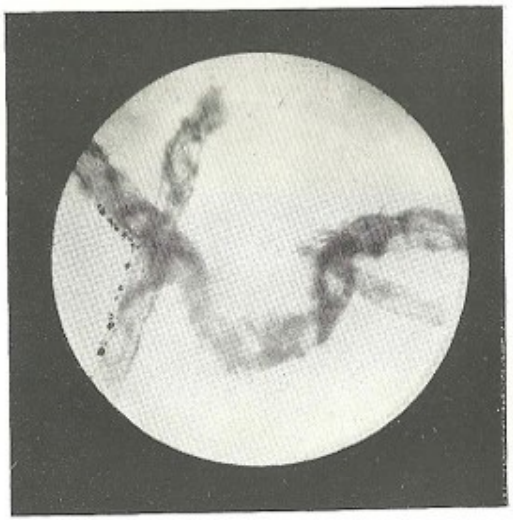

Fig. 53.– Photomicrograph of laundry-worn cotton fibres.

[*To face page* 139.

laundry which showed that cotton cloth lost 2½% of its strength in each hot wash and boil treatment; this is about ten times the rate of wear at a good average laundry. The photomicrograph in Fig. 53 shows laundry worn cotton fibres taken from a table napkin. This table napkin developed holes after 25–30 launderings. In normal laundering it should have lasted at least twice as long. Chemical tests showed this short life was not due to defective fabric or the over-bleaching of the fabric in laundering. In the figure the cotton fibres have been swelled out in caustic soda and stained; ordinary cotton would appear as plain cylindrical fibres, but in this cotton it will be seen that the tough outside layer of the fibres is frayed and broken.

TABLE NO. 16.

Distribution of causes of complaint against laundered goods.

Faults of manufacture	35%
Customers' faults	23%
Laundry faults	19%
Faults not allocated	18%
Action of mice, moths and beetles	2%
Ordinary wear	3%
	100%

The British National Federation of Launderers has a Fabrics Investigation Committee for examining those complaints against laundered goods which are submitted by members of the Federation. In their report of January 7th, 1930, they give statistical results in the examination of 6,813 complaints spread

over a period of five years. The broad allocation of those complaints received is given in the table No. 16.

In the customers' faults about 58% are due to chemical damage arising from the use of stain removers, toilet, cosmetic and medicinal preparations, and acids, and 34% are due to mechanical damage such as cuts, tears and excessive friction in wear. In the unallocated faults the respective percentages are 20% and 61%.

Their analysis of the causes of just complaints against laundering is tabulated below.

TABLE No. 17

Distribution of faults in laundering.

Overbleaching	17·4%
Accumulation of lime soaps	8.2%
Unsuitable detergents	9·7%
Mechanical damage	24.1%
Shrinkage of woollens	4·9%
Other causes	35·7%
	100%

Section 5

The Life of Textiles in Washing and Laundering.—There is naturally great difficulty in giving any " life " figure for the number of washes or launderings of drapery merchandise before the fabric will begin to break down into tears or holes. The original strength and wear resistance of the fabric, the conditions of wear and exposure and many other factors are concerned. Also the more heavily soiled the fabric, the greater the energy required to cleanse

it and so the greater the wear. It is, however, profitable to assemble a few facts which will serve for guidance.

When fabrics must be washed frequently and are also exposed more than usual to boiling, the ease wtth which they can be cleansed is very important. A heavy weight fabric of very tight and close weave may prove very resistant to cleansing, more especially if the yarns have a high degree of twist. The dirt in the yarns is not removable by the agitation and slight rubbing of normal washing and heavy rubbing or even scrubbing with a brush, will be required. This severe wear necessary in washing may more than offset the greater resistance of such a fabric to ordinary wear in use. Two illustrations are some men's heavy overalls and some semi-stiff collars, where fabrics of this type are used. It is worth noting, however, that it is possible to prevent deep penetration of dirt in these fabrics by giving a slight starching after washing. For instance, this treatment will very considerably prolong the life of those semi-stiff collars which normally require heavy scrubbing in order to cleanse them.

In regard to processing there can be wide limits in the wear involved. The duration and severity of the mechanical processes, the use of too little soap, the use of hard water or the indiscriminate use of " chemicals," all may greatly increase the rate of wear.

Linen is a fabric less resistant than cotton to damage by washing processes. In one set of experiments in continuous laundering, linen table napkins withstood 60–100 consecutive launderings before they commenced to develop holes. Experiments[1] following the

[1] *Textile Fabrics*, G. H. Johnson (Harper Bros.), pp. 30 and 123.

U.S.A. Laundryowners' National Association processes, showed that after 20 launderings linen fabric had lost 17% of its strength, whereas cotton fabric had lost only 3·3% of its strength. Other experiments with domestic soap washings only, showed that after 50 washings linen fabric had lost 25% of its strength, while cotton fabric was unaffected. Another feature of linen is that it has much more tendency to crack along the folds made in smoothing than has cotton.

Hemp is stated to be less resistant to washing than linen and to develop a yellow colour.

Wool fabrics can be very resistant to wear and wash, as is illustrated by the wool vests mentioned on page 76, which were still wearable after at least 50–60 washes.

Mention has already been made of one laundry test that showed a cotton cloth lost 2½% of its strength at each hot wash and boil treatment, and that this is at least ten times greater than that occurring at a good laundry. This in itself gives some idea of the possible degree of variation. The following table gives some estimates of the low and high limits of the number of launderings before general breakdown of the fabric may be expected. If the life is below the limit, then either the fabric was defective, the wear severe, or the laundering bad.

TABLE NO. 18

Estimate of "life" of some fabrics in normal wear and laundering treatments.

Starched collars	15–25	launderings.
Shirts	40–50	,,
Ordinary table linen	50–75	,,
Fine damask table linen	40–50	,,
Towels	75–100	,,
Wool underwear	45–55	,,

Section 6

Dry-cleaning.—This process is usually a cleaning with volatile organic solvents, such as petrol or benzene. Its characteristic should be that no water is used. The absence of water prevents shrinkage of fabrics which are likely to shrink owing to their nature, as with wool, or to their structure, as with crêpe yarn fabrics, or to their finish, as with stretched fabrics. It also means that fabrics with colour loose to washing or even to water can be cleaned without colour loss in most cases.

In the cleaning process the fabrics are immersed in a large closed cylinder and solvent containing some special soap is added. After suitable agitation the solution is run off and the fabrics are now given a rinse in clean solvent. In modern machines the inside cage can be rapidly revolved, so throwing out the bulk of the liquid. The fabrics are now dried. The solvent used for the wash and rinses contains in solution all the greasy matters which were on the fabrics, and in suspension dirt which was held to the fabric by grease, or which is detachable by agitation. The dirt is removed by a special filter and thus the solvent can be used again. After using several times it requires to be purified by distillation.

The merits of dry-cleaning have already been mentioned. The defect of this process is that it is only a mild one and dirt ingrained in the yarns is not removed. In consequence, the dry-cleaner cannot always get goods white or very clean by his processes. If goods are very dirty or stained, only soap and water washing (locally or entirely) will give proper cleansing. When goods have colour loose to washing it is sometimes stated that they should only be dry-

cleaned. It is impossible to dry-clean badly soiled fabrics, such as, say, cretonnes and to restore a good white colour.

It is sometimes stated that dry-cleaning disinfects fabrics. This is not so. Experiment has shewn[1] that many bacteria are not killed by the usual dry-cleaning process, and some are not killed by the ordinary live steam pressing process.

[1] Connel Lamson and Drenker. *Journal of Industrial Hygiene*, 1924. Vol. 6, p. 227.

CHAPTER VI

COMPLAINTS FROM CUSTOMERS

Section 1

General Remarks.—When merchandise gives cause for complaint it has either (1) been wrongly used or (2) its qualities were defective or (3) in the case of reasonable use of an ordinary article, the customer's conception of the value obtained for the price paid was wrong. In the first case there is need to educate the customer, in the second case the retailer or the manufacturer is at fault, and in the third case it may be that the advertising descriptions or the selling talk have been over optimistic.

In the table that follows, the results of the investigation in the author's laboratory of seven hundred and fifty complaints have been divided into three large groups. The first group has been termed " Defects in fabrics." The second group is " Disappointments in fabrics," as in this group the blame is only partly with the merchandise. The third group is " Complaints made in error," showing the relative importance of a number of factors that spoil textile merchandise as judged from complaints received. In each group the number of complaints due to each cause is expressed as a percentage.

As some complaints, which were very obviously due to defects in fabrics, would not be sent for investigation, it is not possible to give an exact

distribution of merchandise complaints among these three groups. But as a considered estimate the distribution is approximately: Defects of fabrics 40%. Disappointments in fabrics 20%. Complaints made in error 40%.

TABLE NO. 19

Distribution of causes of complaints against textile merchandise.

Group 1. Defects in fabrics.

Colour defective in reasonable conditions of wear or wash	66%
Shrinkage of fabrics stretched in manufacture	18%
Weak or tendered fabrics	12%
Leakage of proofing of mackintoshes	4%
	100%

Group 2. Disappointments in fabrics.

Shrinkage of crêpe yarn fabrics	10%
,, ,, woollen fabrics	6%
Perspiration damage of weighted silk	11%
Delustred acetate rayon becoming lustrous on damp ironing	7%
Melting of acetate rayon on hot-ironing	17%
Faults due to defective making up of garments (mainly slippage at seams)	25%
Condensation in mackintoshes mistaken for water penetration	18%
Perishing of proofing of mackintoshes	6%
	100%

Group 3. Complaints made in error.

Damage in domestic washing	5%
,, ,, laundry washing	11%
Sulphuric acid damage	9%
Stains not due to fabric or loose colour from the fabric	13%
Other accidental damage (cuts, tears, burns, etc.)	33%
Normal wear and tear	12%
Various causes	17%
	100%

The investigations show that the principle defects in textile merchandise are as follows and in the order given: (1) defective colour fastness, (2) shrinkage of fabrics that have been stretched in the finishing processes, (3) insufficient strength which may be due to structure, or to the nature of the yarns, or to tendering in manufacture, and (4) thread slippage either in the body of the fabric or more usually at the seams. The following four sections will deal with these subjects so far as complaint investigation is concerned. The general treatment of them has already been given in preceding sections of this book.

The class of "Complaints made in error" contains a large proportion of causes of damage which the customers may reasonably attribute to the fabric until the cause is elucidated. This applies, for instance, to laundry damage, and to stains not due to the fabric or the colour in the fabric, and to some types of accidental damage. In particular, however, it applies to sulphuric acid damage. This is a trouble

that is very largely concerned with radio sets. The acid in the accumulators is very likely to leak or spill, and because it is not immediately corrosive nor painfully irritant to the hands, its potency is often not realised.

It is remarkable how varied are the articles damaged by sulphuric acid. Damage on towels, kitchen-cloths, carpets, and even on silk hose is not unexpected. Probably the holes in a silk dressing-gown indicated that a radio enthusiast had risen from bed to receive American broadcasts. But were the holes in a blanket due to a super-enthusiast who takes his radio set to bed ? The hole in the top left shoulder of a silk frock seemed eloquent of the affection of the radio listener.

It is important to remember that accumulator acid will not damage wool, but all other fabrics are tendered by its action. The blanket mentioned in the previous paragraph had a cotton warp and a wool weft. The weakening is not immediate. This means damage may only be discovered a day or so later, or even after washing or laundering ; also as the effect follows the cause after a lapse of time it is certain that in many cases the customer believes the fabric has " rotted " and so was defective. Fortunately, in most cases acid is still present and can easily be detected in the laboratory, or even a simple test with litmus paper will give definite results. But even after acid has been washed off, it is often possible to prove it has been present. When told the facts or shewn a report customers are usually reasonable.

When fabric has come into contact with acid, the first thing to do is to rinse it immediately and thoroughly. Provided this is done little harm will

result. Where this is not easily performed, as with, say, carpets, neutralise the acid with some alkaline substance. The best is ammonia, and if no household ammonia is present, then smelling salts will be as good. Washing soda solution is good, or failing this use bath salts (more expensive, and scented, but usually the same thing).

Apart from any action on the fabric, acid will often affect colour. For instance, splashes of acid on a blue wool fabric will usually leave the colour red, and on some red colours they may produce a deep blue black. Treatment of the affected portions with ammonia will very often restore the colour.

Among the various causes for complaint, damage by marking ink deserves notice. Most marking inks contain some acid or oxidising agents, and if left long in contact with cellulose fabrics (cotton, linen, rayon) they will cause tendering. If the ink markings are ironed before they are washed, then very serious tendering may occur. The ironing of marking inks to fix them was only necessary on the old silver nitrate marking inks which are not now used, and which would be objectionable on goods sent to be laundered, as they would cause severe local action by any bleach used, and so tender the fabric. After marking, goods should be washed within two days, and they should not be ironed until they have been washed.

The mackintosh problem is one of interest, and two aspects of this (condensation and leakage at seams) have already been discussed on pages 50-51. As the problem is essentially connected with the rubber-proofing a few notes on rubber are included in this section.

The growth of the rubber industry truly started

with the discovery of the process of vulcanisation by Goodyear in America in 1839 and independently by Hancock in London in 1844. This is a process wherein certain chemicals are incorporated with the rubber and then caused to re-act by some agency, usually heat and pressure, forming a product of markedly different and superior properties to untreated rubber. Sulphur is nearly always used; for soft rubbers 5–10% of sulphur is added and for hard products (ebonite) 50% of sulphur is added. After treatment in one case about 3% of sulphur has combined with the rubber and in the other case about 30%. The " bloom " on rubber is due to a fine layer of uncombined sulphur. The ordinary curing requires several hours at high temperature and pressure; by adding very small quantities of organic compounds known as accelerators this is reduced to several minutes and perfect vulcanisation is secured when only 0.5–1.0% of sulphur has combined with the rubber.

" Cold curing " or cold vulcanisation is a different process. In this case the rubber is immersed in a 3–5% solution of sulphur dichloride in carbon disulphide and the sulphur dichloride combines, giving vulcanisation. The process is only applicable to rubber in thin sheets and is used in the rubber-proofing of fabrics.

" Pure rubber " should be vulcanised rubber only. Such a product may be too soft and elastic. Substances are usually incorporated, therefore, with the object of improving the rubber for special purposes, but also very frequently purely to cheapen the article. The various types used are:—(1) Filling materials solely to cheapen the article, as chalk, reclaimed

rubber, and factis (or oil substitute); (2) materials for specific purposes, (*a*) mechanical strength is increased by zinc oxide, magnesium oxide or carbonate, lime, litharge, balata; (*b*) dense, non-porous mixings are secured by adding asphalt, pitch, bitumen, ozokerite; (*c*) vulcanising conditions are improved by litharge, lime, magnesia, antimony sulphide, or organic accelerators; (3) dyes or pigments may be added to give colour. Reclaimed rubber is made from rubber scrap, such as old motor tyres, etc.

The quality of rubber goods depends on the mixture used and on the degree of vulcanisation. Excess of free sulphur does not affect the original qualities, but later in use, after-vulcanisation will occur, producing a hard and brittle product. All rubber absorbs oxygen from the air, becoming either hard or gummy. The ageing or perishing is greatly accelerated by light (particularly direct sunlight) and by heat (especially dry heat); the presence of certain fats or oils has a considerable accelerating effect, and examination by the author of returned mackintoshes indicates that perspiration is a considerable factor owing to the fatty matters it contains. Certain metals, notably copper, cause very rapid perishing of rubber, and so dyed cloths, used for mackintoshes, etc., must not contain any traces of copper salts. Over-vulcanised rubber possesses excellent properties at first, but soon ages; and the more a rubber is adulterated by filling materials the more rapidly it perishes. Rubber that is coloured is likely to last longer than uncoloured rubber, as the colour absorbs much of the damaging ultra-violet light, and black coloured rubber is best of all in this respect.

It is difficult to lay down any standards for the life

of rubber. On the light-weight silk and rayon mackintoshes the rubber is exceedingly thin (say four-thousandths of an inch thick) and the open weave of the fabric permits much light penetration. The general life seems to be over one year, but a life of over two years is not to be expected if a garment is worn much and exposed to light. In mackintoshes with a stout, closely woven wool or cotton face the useful life may be much longer, as light penetration is much less, and a garment with rubber between two cloths closely woven gives the best conditions for long wear. As mentioned already, the principal enemy is light, and then grease and heat; a garment will last longest if hung to dry and then stored in a wardrobe. When a rubber layer is outside, as in some mackintoshes, the worst conditions for life are given.

In testing rubber, analysis is not of great value. Tests of breaking strain, elongation to breaking point, before and after some ageing treatments are of most value. Fair to high class soft rubbers should possess a breaking strain of 1,500–2,500 lbs. per square inch and should have an elongation at break of 700–900%; medium rubbers, 1,200–3,000 lbs. and 500–700%. Under-cured rubber has a high extensibility and low breaking strain; over-cured rubber the reverse; when both are low a filled rubber of low grade is indicated. When the extension to break of soft rubber is below 400% it must be regarded as poor, and if below 200% as practically worthless material.

In the rubber-proofing of fabrics the material is passed through rollers and a very thin film of the rubber mix is laid on the fabric. Any small bubbles of air in the mix will mean that spots on the fabric are not proofed, and so about five or six separate

layers are successively applied to ensure an even result. The fabric and proofing then pass through the vulcanising process. It is to be noted that if any pieces of grit get into the mix they will cut the cloth as it passes through the rollers. Occasionally mackintoshes will develop long straight slits that are clearly due to cutting in this way; until some slight stress occurs in wear the rubber holds the cut fabric together.

Proofing containing excessive filling may be porous or may perish rapidly in use. With under-cutting in the price of proofing this has been a serious problem.[1] On one lot of mackintoshes examined by the author, the proofing contained so much oil substitute in place of rubber that it was as soft as an artist's india-rubber eraser, and rubbed away quite as easily.

The presence of many air-bubbles is a sign of defective proofing. These are easily detected when the fabric is held up against a strong light. Each bubble has only a very thin coating of rubber and with age it will develop into a pin-hole through the proofing. Any pin-holes in the proofing will show in this inspection by the distinctly greater brightness than air-bubbles. Moreover, if such spots are marked with a piece of chalk, and the fabric is then held to a water-tap, the penetration of water is clearly demonstrated.

The pool test is a valuable one in showing up porosity in rubber proofing on fabrics. A pool about four inches deep and six inches in diameter is formed, with the fabric side innermost. Any penetration shows as wet spots or drops of water. The test should

[1] Blond. *Transactions of the Institute of the Rubber Industry*, 1927. Vol. 3. p. 234.

continue one hour, and a good fabric will show no penetration.

Section 2

Colour.—The general facts about colour and its fastness have already been discussed at fair length. The purpose of this section is to assist in the assessing of colour complaints against merchandise.

Fading that is due to light has two characteristics. One face of the fabric will usually be more faded than the other and any covered portions will have sharply defined areas of little or no fading. The duration of use and the type of weather over the period must be considered in assessing the degree of blame attached to the fabric, for ordinary commercial dyeings are certainly not fadeless. In ordinary dyeings bright blues and greens are often fugitive and basic dyes on silks are bright but fugitive. Basic dyes are usually used on straw hats, and in fact are necessarily used in some cases because they are the only ones which will penetrate ; in consequence colours here may be very fugitive.

About 5% of women's wool dress fabrics are unfit for sale for outdoor wear, on account of low light-fastness, and with silks the proportion is probably at least 15%.

Until matters have improved a proportion of "fadeless" furnishings will return with complaint of fading. On one occasion the entire "fadeless" fabrics of a shop were tested. There were 43 ranges, comprising 339 colours. They were all good average fabrics and the shop was one that sold good average merchandise. The colours were tested for fastness to light, weathering, washing and hot-ironing, and for type of dyeing.

Fig. 54.—Characteristics of light fading of coloured fabrics. The exposed portions of the folds of this window drapery are most faded, and the inside of the hem shown opened up is not faded.

(Courtesy of the Department of Research, Laundryowners' National Association of U.S. and Canada.)

[*To face page* 154.

The resultant grading was: "Fadeless" . . . 182; Fast to light and washing . . . 81; Fast to light only . . . 17; Ordinary quality . . . 46; Not fast (for furnishing fabrics) . . . 13.

The defective colours were largely in 9 ranges of 37 patterns, mainly direct cotton dyeings. The colours on these patterns were graded: "Fadeless" . . . 2; Fast to light and washing . . . 1; Fast to light only . . . 6; Ordinary quality . . . 18; Not fast . . . 10. A selection containing at least 80% of trouble making colours if sold as "fadeless."

The remaining 34 ranges of 302 patterns were graded: "Fadeless" . . . 180; Fast to light and washing . . . 80; Fast to light only . . . 11; Ordinary quality . . . 28; Not fast . . . 3.

Judging from this it can be seen that unless tests are made at least 17% of "fadeless" fabrics may be falsely described and trouble producing, and only about 54% will be "fadeless" to a rigorous commercial standard, while to a tolerant standard probably only 75–80% will be correctly described.

In complaints concerning silks (including hose) with regard to colour loss when washed it is always advisable to try the effect of a spot of dilute acetic acid on the fabric. If the defect is due to alkali sensitive dye this will restore the colour. A proportion of French dyed "washing silks" and silk hose and underwear have alkali sensitive colours. In France it is usual to finish the washing of silks with a weak acid rinse, and so no trouble occurs. The suitable final treatment has been given on page 125.

In the case of complaints against fabrics known to be satisfactory in normal use, hot-ironing effects may be suspected. Careful inspection of the article will

often give evidence when such damage has occurred. The shape of the iron may show, or more frequently it will be found that where two thicknesses of cloth overlap the protected portion is unaffected. Care must be taken to ascertain that such colour-change is not due to sunlight fading. In a complaint the author investigated against "fadeless" casement, the actual cause of the fading was hot-ironing.

When fabrics are soiled the colours are dulled and the appearance may be similar to sunlight fading. In a complaint against a carpet for fading, the cleansing of a small portion showed that no colour loss had occurred.

Where complaints of staining from fabrics are concerned and the colour is loose to dry rubbing, no defence of the dyeing is possible, but if the colour is only slightly loose to wet rubbing, then the dyeing is not of good quality, but in consideration of the standards at present obtainable it cannot be classed as of objectionable quality. In all cases of staining of the skin it is important to remember that the colour is not dangerous to health (see page 97).

Many people appear to believe a re-dyed fabric is defective. This is not necessarily true. The actual process of re-dyeing should not damage a fabric, and so where a fabric is re-dyed because the shade is unfashionable or to cover slight colour defects or fading with a deeper colour there may be no grounds for objection. On the other hand a fabric may be re-dyed to cover serious fading which has tendered the material, or because defects in the material show in light colours and will be covered by deep colours, or, of course, in some cases a fabric may be tendered or impoverished in re-dyeing. As mixtures of dyes are used in securing

shades when a fabric is first dyed, it may be impossible to state whether any additional dye has been added in a re-dyeing operation; frequently, however, analysis will show whether a fabric has probably been re-dyed.

Section 3

Shrinkage.—Complaints of shrinkage against ordinary woollen fabrics may be due to (1) stretched material, (2) careless washing or (3) severe washing or (4) accidental washing with white cotton goods.

In shrinkage due to stretched fabric, there will be no evidence of felting or "thickening." The question of stretch can only be investigated by soaking a new garment or new portion of fabric in tepid softened water for several hours and then drying, measuring, and then damping, and ironing damp and measuring again. In the twenty-one "unshrinkable wool" undergarments tested (see page 74) the losses in area on soaking were: 5% and under . . . 10; $7\frac{1}{2}$% to 5% . . . 4; 10% to $7\frac{1}{2}$% . . . 4; over 10% . . . 3. The losses in the last three were $12\frac{1}{2}$%, 14% and 15%.

In very exceptional cases the shrinkage may be due to crab-finished woollens (see page 66). To test this, a piece of fabric of known size should be left in a soap solution near to boiling point for one hour and then cooled, rinsed, dried, and measured ironed dry and ironed damp. In this treatment, care must be taken that the fabric receives no rubbing, not even such as could occur in the turbulence of a boiling liquid. The shrinkage of crab-finished goods would be evidence of very hot, and so improper, washing treatment, and should not be taken as a fault in the goods.

Shrinkage due to careless washing (that is to say

with an undue amount of rubbing or mechanical action) will probably require four or five washes before grounds for serious complaint occur. With severe washing (that is with both undue rubbing or mechanical action and wash liquor at high temperatures) two or three washes may make the garment unwearable. In the case of accidental washing, such as inclusion in the cotton boiling wash, very severe shrinkage will occur in one wash, and shrinkage of the order of 20% to 30% in length may be expected.

If complaints of shrinkage are accompanied by the statement that the washing was done with some preparation that will not shrink woollens, only one course should be pursued. The claim should at once be referred to the makers of the preparation. The author has no knowledge of any preparation that will wash woollens without shrinkage if rubbing is used, and he does not believe such a preparation can exist. People using such attraction to sell their wares must take full responsibility.

Where "unshrinkable woollens" are concerned only one course is possible. The claim must be met at once and then referred to the manufacturer. No excuse can be made if the "unshrinkable" becomes shrunken.

In cases of alleged shrinkage of ready-made items such as shirts, collars, vests, socks or frocks, comparison with an original item will give some information. First, however, make sure the complaint is really due to shrinkage; for instance, if a customer has ordered 10 inch foot hose and received 9 inch foot hose, then a shrinkage complaint is not unnatural. Simple weighing of an original and a returned item will often show if they are of different sizes. The degree

of shrinkage, if the original dimensions are unknown, can be estimated by comparison of the reed and pick (warp and weft threads) per inch. For instance, it is clear that any shrinkage in width means that there are more warp threads per inch; say a 30 inch wide material has 3,000 warp threads, i.e. 100 per inch, and it shrinks to 25 inches in width, then it will have $3{,}000 \div 25 = 120$ warp threads per inch. If the increase in warp threads per inch is divided by the increased total of warp threads per inch and the result is multiplied by 100, the percentage shrinkage in width is obtained. In the above case $100 \times (120-100) \div 120 = 16.67\%$, or one-sixth. The same process of calculation applies to weft threads per inch giving length shrinkage. With knit fabrics the count is concerned with needles and courses.

If shrinkage is found, the next question is does it disappear or decrease in ironing evenly damp? If so there is the cure. If not is the shrinkage natural to the fabric, or is it so small as to be reasonable, or is it unreasonable? In ordinary light fabrics one cannot cavil at $2\frac{1}{2}\%$ shrinkages in width and in length, and shrinkages of $2\frac{1}{2}$–5% do not give much ground for complaint, but over 5% shrinkage is undoubtedly objectionable. In heavy fabrics and men's suitings, the shrinkage should be less than 3%. Reference is directed to the shrinkages given on page 70 in Table No. 9.

Section 4

Damaged Fabrics.—When fabrics are returned damaged the problem of ascertaining the cause of damage and allocating to various factors the degree of blame is a very involved one. A few general hints can be given, but the investigation of a complaint

of this sort is usually an interesting but self-contained problem which must be solved by observation, experiment and deduction, and no general rules can be laid down.

The first requirement is the history of the item so far as it can be ascertained. How long has it been sold, how long has it been in use, and under what conditions? The statements and opinions of the person making the complaint should always be available for consideration. Any of the facts given in the preceding sections of this book may be pertinent in assessing the merit of a complaint. Sometimes damaged fabrics are simply worn out fabrics. For instance, pillow cases wear thin in the top middle portions, and sheets just where the weight of the body produces frictional wear, and the wrist bands and elbows of sleeves are worn away by those engaged in clerical work, and the seat portions of garments by those engaged in sedentary occupations.

Are there any true holes in the material, that is, places where the fabric has vanished? In the cases of tears or cuts the edges of the damage will more or less join, though, of course, some allowance has to be made for the inevitable fraying of the edges which may occur in wear or wash. If the damage is a true hole with material vanished, the cause could be (*a*) rubbing away by slow but continued friction in wear or by sudden and severe friction as produced, say, in a fall and sliding along a rough surface, or (*b*) by an accident which has destroyed the fabric, as, say, a burn from a cigarette end, cinder, match, or severe local scorch in hot-ironing, or, alternatively, from acid damage or other destructive chemicals getting on the fabric, or (*c*) in woollens it may be moth grub damage. Where

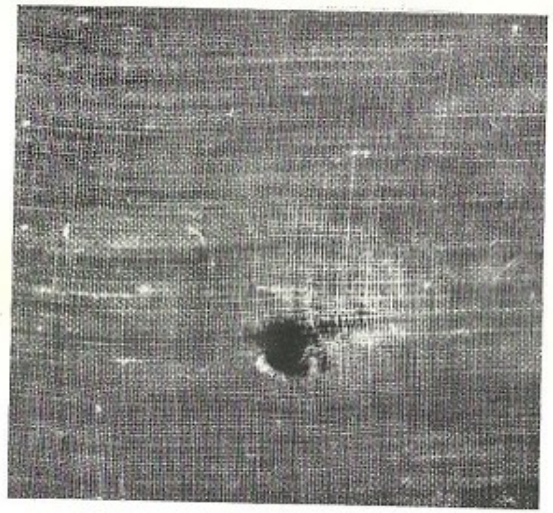

Fig. 55.—Hole in a fabric caused by rubbing wear.

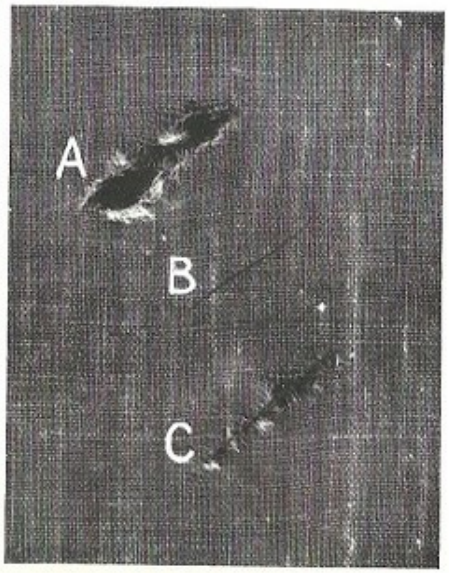

Fig. 56.—Cuts in a fabric: A as usually found enlarged and with edges badly frayed by laundering; B an original cut; C a cut slightly enlarged and frayed after one laundering.

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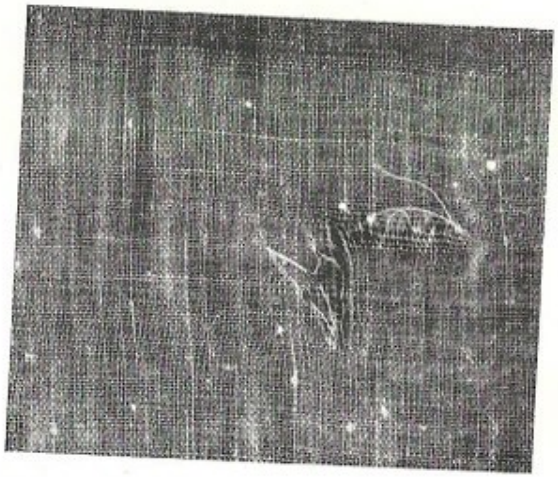

Fig. 57.— A right-angled tear or jag such as is produced when cloth is pulled and torn after catching in a nail or thorn.

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the hole is due to general wear the fabric around will be weak and thin (see Fig. 55); hand tests for strength and holding the fabric up to the light will show the general wear. But if the fabric is strong all round the hole, the probability is that some accident has occurred. Closer inspection may reveal signs of scorch, or a test with litmus paper may show that acid is present.

Or is the damage due to a tear or a cut? When a normal fabric tears it does so along either the warp or the weft. Line effects across either of these must be cuts, and they may be straight, such as would be

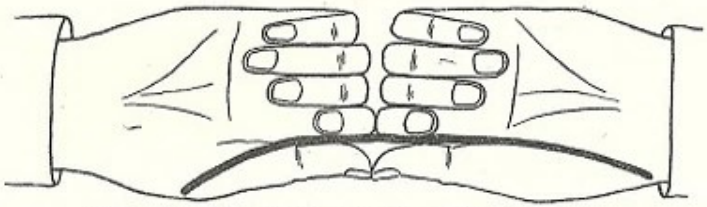

Fig. 58.—Thumb test for strength of fabrics

produced by a knife on a table-cloth or kitchen-cloth (see Fig. 56), or they may be jagged, as would be produced when cloth gets crushed between irregular surfaces or cut on broken glass, or they may be some regular shape, if, say, a button causes a part circular cut in a cloth during mangling. In the case of tears, not much can be observed unless one has a jag or right-angled tear (see Fig. 57), when it will be realised that this is the type produced when a cloth catches on a nail or a thorn.

The next step is to test the strength of the material first around the damaged area and then on some other place. For the second test a place should be chosen where any small damage will not matter, or be noticeable; it is often possible to perform tests on the turn-

ing of a seam. The hand tests given for fabrics are not suitable here, for the tears produced would be too severe. The preferable test is the thumb test. Take a similar grip on the cloth to that described on page 38, having the tips of the thumbs together and the thumbs fully straightened out. Now turn the wrists through 180°, when the cloth will be as shewn in Fig. 58. Now by bringing the wrists towards each other with the thumb-points as fulcrum, a very heavy local leverage can be obtained. Most light fabrics can be broken by this method, but the ease of breaking gives some indication of the strength ; and the special advantage is that only a very small tear need be produced.

If the fabric is found to be weak, it may be due to defective fabric, or normal tendering in wear, or the light nature of the fabric, or improper treatment. Test several similar fabrics of different makes. This will show whether the fabric is of normal strength.

Assume it is found to be weak only locally. Then some unusual factor has operated. Is it weighted silk ? It may be the effect of light, or of light and perspiration. With other fabrics it may also be the result of light tendering, as say in frock fabrics or casements. The " dropping " of net curtains is usually the effect of light tendering on a fabric initially rather weak. The fabric should be tested to determine whether it is weak or strong in various portions as would be expected from the hypothesis. If agreement is found in a number of cases, the hypothesis is strongly supported. Or it may be heat damage or chemical damage ; again inspection may give some decisive evidence. On the other hand, it may be some defect in the fabric, and so it is very necessary to make a general examination of the cloth for defective places,

such as knots due to joined up yarns, or for thin and weak portions in the yarns, or for places where some defect has occurred during weaving. Also consider that some defective or weak yarns may have been used in the warp or weft, and of course in this case the defect or weakness will almost certainly be right along the length or right across the width.

Assume the fabric is found to be generally weak. Was it tender material or is it due to misuse ? It may be impossible to say. But if the item contains any sewing thread or two different pieces of fabric (as, say, a lace or fancy border) valuable evidence is available. If the material and the sewing or the other fabric are both tendered, the damage has almost certainly occurred after the making up, and it has probably occurred in washing or laundering ; but if, say, the sewing is strong but the fabric is weak, then it is very probable that the fabric was defective.

Section 5

Defects in Making Up.—The correct cutting of the cloth and the correct assembling of the portions have much to do with the satisfaction given by a fabric in wear.

One common cause of complaint is the defective making of long, tight-fitting sleeves. The special point in these sleeves is that elbow room must be left. The two patterns used in long sleeves are given in Figs. 59 (*a*) and 59 (*b*). In Fig. 59 (*a*) it will be seen that one edge is longer than the other, and two notches, A and B, are marked opposite the elbow and in the short side, two other notches, much closer, are C and D. When sewing up the sleeve the excess length of the AB edge is gathered in or pleated by making AB and

CD meet, and this gives elbow room. Cases of burst seams in long sleeves of frocks occur (1) when both edges are about equal in length, (2) when the excess

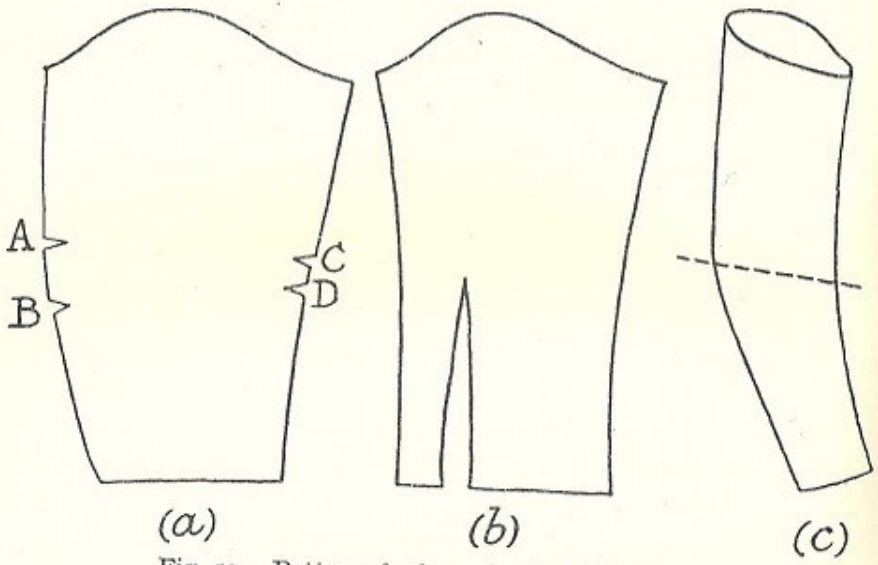

Fig. 59.—Patterns for long closely-fitting sleeves.

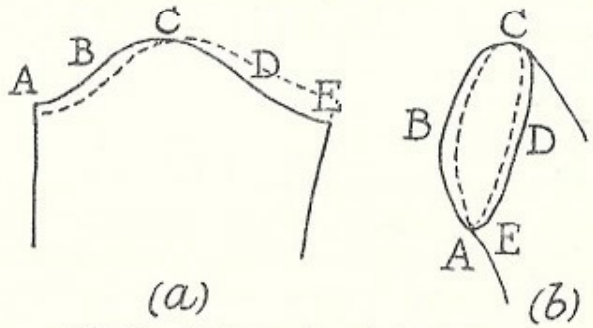

Fig. 60.—Pattern of arm-hole of sleeve.

length of the AB side is evenly eased in all along the CD side, (3) when the excess length of the AB side is not gathered in opposite the elbow but at some point above or below. The other method of giving elbow

room is by a dart cut out as illustrated in Fig. 59 (*b*).

Another trouble in amateur dressmaking is the fitting of the sleeve in the arm-hole. The correct outline for the top of a sleeve is shewn in Fig. 60 (*a*) and the assembled sleeve in Fig. 60 (*b*). If in cutting the back ABC is not full enough, this makes the sleeve ill-fitting at the back and in wear it will be very tight across the shoulders, and so it is probable that seams will be burst at the back of the shoulders, or the cloth will be torn. Failure to scoop out enough for the front, CDE, means there will be excess of cloth at the front, and this will throw back the sleeve. If the arm-hole is cut down too low there is a very heavy pulling strain on the seam under the arm-pit when the arms are lifted, and the cloth or the seams may burst. This cause of complaint is met in ready-made frocks as well as in home-made frocks.

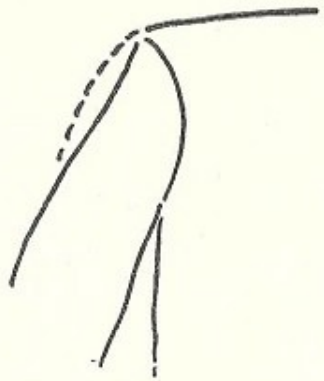

Fig. 61.—Shape of wrongly-fitted sleeve.

In one complaint concerning a long-sleeved frock, each sleeve had been fixed in the wrong arm-hole. This meant first that the seam which should be on the inside bend of the sleeve was on the outer bend, where it received most strain, and in place of room at the top of the sleeve, the cloth set in as shewn in Fig. 61 . Bursts occurred in the seams along the sleeve and at the top back of the shoulder.

When frocks are bought (or sold) some attention to special points of fitting will do much to ensure satis-

faction. In a long-sleeved frock make sure the sleeve is not too tight when the arm is swelled by the tensing of muscles when bending up the arm. Next inspect the fit across the shoulders. If it is a very perfect fit, it is probable that slightly unusual strains will burst the cloth or the seams at the back of the shoulders. Then lift the arms outward and upward. Any pull of the sleeves on the biceps or under the arms means the arm-hole is too large or too low. If the frocks

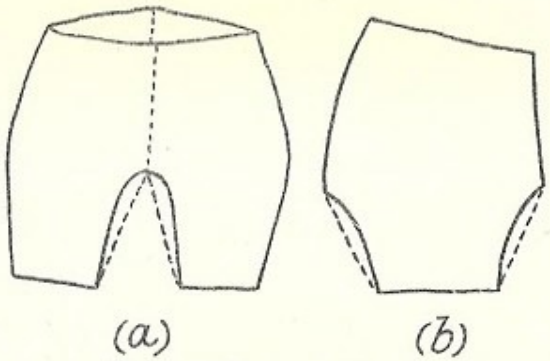

Fig. 62.—Patterns of knickers.

are washing frocks, remember that some shrinkage is probable in washing. A fit that is fairly loose is the safest.

A complaint investigated was concerned with a fine linen made into knickers. After two periods of wear the cloth had worn into holes in the top inside portion of each leg. The cloth was of excellent quality and the defect was in the making up. When laid flat ordinary knickers appear as in Fig. 62 (*a*) with the top inside of the leg rounded off. This is secured in straight cut patterns by inserting a diamond-shaped gusset. The knickers examined had no gusset and the inside leg portion was a straight V, as shewn in dotted lines in Fig. 62 (*a*). It will be seen that this

leaves loose fabric which will naturally rapidly chafe away in walking. The pattern that should have been used is shewn in Fig. 62 (*b*) and the wrong cutting is shewn by the dotted lines in that pattern.

Another case of wrong cutting out was a child's frock which had burst at the sleeves. These were magyar sleeves, and the correct type of sleeve is shewn in Fig. 63 (*a*), while the dotted line shews the actual shape. The cutting out of the sleeve should have been as in Fig. 63 (*b*), but the dotted lines show the cutting used in this case.

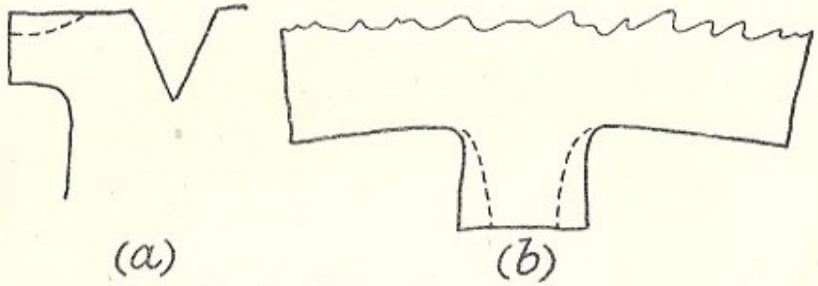

Fig. 63.—Pattern of magyar sleeves.

Where piece goods have given unsatisfactory wear and the cloth appears to be quite satisfactory, then a competent dressmaker may be able to solve the problem.

Given a correctly cut material the next requirement is correct sewing. The slippage of woven fabrics has already been mentioned. Seams must have sufficient turning. Moreover, there are many varieties of seams, and sewing can be close or open, and with proper making up attention will be paid to these points. If two parallel rows of close stitching are used in making seams, then the risk of thread slippage in the fabric is greatly reduced. A very common fault, however, is concerned with the sewing of knit

fabrics. The special characteristic of knit fabrics is their elasticity. Now sewing thread does not stretch appreciably, and if a knit fabric is sewn in the normal state, then all strain in stretching is taken by the sewing, and it usually bursts. In sewing knit fabrics the fabric should either be sewn when it is stretched or the sewing thread must be very strong. In nine successive samples of different makes of rayon stockinette knickers examined by the author only three had been properly sewn, for in the other six a moderate pull at the elastic waist broke the sewing.

In machine-sewn fabrics, damage may occur if the needle is very blunt, or more especially if its point is broken off. The needle, instead of sliding past or through the yarns of the fabric, cuts its way through the yarn, and early in use the material tears away at the seams. This type of damage is very easily recognised.

The table below gives an analysis of twenty consecutive complaints mainly due to defective make-up. Some garments had several defects.

TABLE NO. 20

Distribution of some causes of complaints against made-up garments.

Long sleeves—burst along seams	6
,, ,, —correctly cut but incorrectly sewn	2
Tight fit across back—burst at back of shoulders	5
Tight fit under arms—burst under arms	4
,, ,, general, leading to burst seams	2
Insufficient turning of seams	4
Faulty cutting out	3
Faulty machine sewing (ends of threads not tied or bound)	1

CHAPTER VII

CONCLUSION

THE general subject of the service values of textile merchandise has now been surveyed and a few criticisms and constructive suggestions will form a fitting conclusion.

Nowadays the old commercial standards of buying as cheaply as possible and selling as dearly as possible, with " caveat emptor " (let the buyer beware) as the business motto, are somewhat out of favour. The talk is now of " service " as an ideal or even a standard in business ; and while the cynic may doubt the reality of ideals in business, there is no doubt that, in the younger generation especially, considerations of public-spirited service are truly a powerful motive.

It will be clear there can be two extremes in standards in merchandise : one of minimum satisfaction qualities and one of maximum satisfaction qualities. By minimum satisfaction qualities is meant merchandise in which the volume of complaints is such that reclaims can be met and still leave a profit. By maximum satisfaction qualities is meant merchandise in which care has been taken to eliminate every probable cause for dissatisfaction, so far as is possible at the price. Unfortunately as yet the standard of maximum satisfaction qualities is not general among manufacturers, and in fact considera-

tions of minimum satisfaction appear to operate even in some very large manufacturing organisations.

The deplorable result of this position is that it involves immense wastages in time, money and human happiness. For people of smaller incomes it also has some of the elements of tragedy, as money is not available to replace merchandise which is unsatisfactory or defective.

The application of the simple tests given in this book (see the index under " Tests ") will eliminate a large proportion of defective merchandise and the intelligent use of the facts given will make the distributor more sure that his merchandise will give satisfaction in use.

The need of the times is very clear. Already there exist research organisations concerned with the various branches of the textile industries, and these organisations are doing very valuable work. But the reseacrhes with which they are concerned deal almost entirely with problems relating to manufacture. There has not as yet been any deliberate study of the service value of textile fabrics in conditions of use, and so there is a lack of knowledge concerning this most important point. The manufacturer, distributor, consumer and launderer have very real mutual interests, but these receive no study. What is needed is a Textile Distributors Research Association which would forward the interests of all four parties.

As a preliminary this Association (hereinafter referred to as the T.D.R.A.) would assemble all the available facts ; this book is a step in this direction. These facts would in the first place be rendered available to the manufacturer and the distributor by

lectures and technical publications. With an intelligent understanding of such facts on the part of retail buyers and salesmen it would then be possible to undertake the education of the public by lectures, and by advertisements with selling appeal based on the statement of facts in place of mere assertions, and by intelligent " selling talk " and guidance by the salesman behind the counter. The public have been taught to judge merchandise by the price appeal, and by the superficial qualities. Experience has shewn that where an appeal based on an intelligent statement of qualities and value is made, the results are very satisfactory.

The object of the Research Association would not be to conduct extensive and expensive researches into the qualities of textile fibres and the nature and effects of manufacturing operations. These researches are the concern of the manufacturers and they are already receiving the attention of the existing textile research associations. It would concentrate on the qualities of textiles in the conditions of use, gaining much of its information from the investigation of complaints from customers, but also conducting properly devised experiments. As a result it would be in a position to define the problems facing the distributor and to place these in a proper manner before the appropriate organisation for detailed investigation.

Work of this type has already been performed in this country by the Fabrics Co-ordinating Research Committee, but it has been restricted more to problems concerned with the Naval and Military Services. Possibly similar work for the interests of both the textile industry and the consumer could be undertaken by the Empire Marketing Board or the Con-

sumers' Council. In U.S.A. some work of this type is being done under the Bureau of Standards, and other work is being performed by various universities.

Another aspect of this Association would be that it would form a connection between the various sections of the textile industry. When the manufacturer introduces a new product of special merit (such as, say, vat-dyed silks), he finds great difficulty in securing proper appreciation from the distributors. But if all new products were reported on by a scientific body fully aware of the problems and the needs of the distributor, then those products which were good would receive proper attention. Again, when a distributor finds there is need for some special product he is not able to determine how far it is possible to meet such needs; the investigation of the problem and its presentation in proper form to parties likely to be able to manufacture the product will undoubtedly ensure more rapid progress in the improvement of the qualities of textile merchandise.

After a period of experimental researches and of discussions with other textile research associations, scientific workers, and manufacturers, the T.D.R.A. would be in a position to formulate minimum standards for certain generally useful trade descriptions, such as "Fadeless," "Fast Colour," "Unshrinkable," "Rain-proof" and "Shower-proof," and it would also determine the minimum standard of qualities required in various types of merchandise. At this stage it would be opportune to consider the issue of T.D.R.A. tabs which could be attached to tested and inspected merchandise. This process of sampling and inspecting is already used by Governments in the purchase of their supplies, and it could undoubtedly be applied simply and commercially to much of drapery merchandise.

In Germany a tab marked "Indanthrene dyed" is attached to goods which conform to a definite and high standard of colour fastness, and in U.S.A. a similar "Nafal" tab is used. The Indanthrene tab is restricted to goods dyed with the products of the German I.G. manufacture. The Nafal tab has no such restriction; any American manufacturer may submit his fabrics to the tests and sampling of the central laboratory concerned with the Nafal standards, and if the colour fastness is of the requisite standard he may affix Nafal tabs, whatever may be the source of the dyestuffs used. These schemes have both proved very successful, and deservedly so, for they do definitely assure a high standard, whereas the public know from experience that the ordinary claims of "fast colour" products are not always well-founded.

There will always be some merchandise based on design and fashion appeal to which a special standard of utility cannot easily be applied, and there will be general merchandise sold that is not tabbed. As a matter of public interest the T.D.R.A. would perform tests on all varied types of merchandise. From time to time it would meet products of such inferior qualities as to render them very undesirable. In cases of this nature some manufacturers at present show a lack of concern; the goods have the minimum satisfaction qualities, and if one shop or store does not care to buy the product the loss in trade is not serious. But if the T.D.R.A. approached a manufacturer with the statement that his goods were sub-normal and that they would like his remarks

before circulating their experimental results to its members (who would include nearly all the textile distributing trade), then it is probable some action would be taken.

These developments, however, have yet to fructify, and the author can only conclude his book with the hope that the general facts herein assembled will prove helpful in some degree to the manufacturer who desires to improve his products, to the retail distributor who wishes to sell service and satisfaction with his wares, and to the consumer who will have some guidance both when making purchases and in the subsequent periods of usage and laundering.

APPENDIX

Some books and references to technical literature concerning textiles

FOR those who desire to read further into the various subjects discussed, the following list of books and of references to technical literature will be of interest. The bibliography does not pretend to be in any way exhaustive, but it provides sources for more detailed information than is necessary in a broad consideration of the wearing and washing qualities of textiles.

Textile Fabrics, by G. H. Johnson (Harper Bros., New York and London), discusses the subject from a general point of view. The author is in charge of the Department of Research of the Laundryowners' National Association of the United States and Canada.

A Textile Guide for Retail Distributors, by W. W. Halstead (Ernest Benn), is a volume that should prove a useful supplement to *Textiles on Test*. The author has considerable experience in testing textiles for retail distribution. The book contains an extensive glossary giving details of the structure, weight, fineness of weave, and the variations in the various types of fabrics.

Fibres for Fabrics, by A. E. Garrett (Hodder & Stoughton), gives an interesting survey of the subject indicated by the title.

Another general survey of the subject is a small book, *Cotton, Linen, Silk and Woollen Fabrics*, by H. B. Heylin (Heywood).

Pitman's have published a Common Commodities and Industries series. Among these small volumes are :—*Cotton* (R. J. Peake), *Linen* (A. S. Moore), *Wool* (I. A. Hunter), *Silk* (L. Hooper), *Knitted Fabrics* (I. Chamberlain and I. H. Quilter), and *Carpets* (R. S. Brinton).

For general information on textiles, the articles in the *Textile Recorder Yearbook* and the *Textile Manufacturer Yearbook* are very useful.

Books which will supplement various sections of *Textiles on Test* are :—*Dyeing with Coal Tar Dyestuffs*, C. M. Whittaker (Baillière Tindale & Cox), *Control of Laundry Operations* by R. G. Parker (Published by the British Launderers Research Association), and *Dyeing and Cleaning* by F. J. Farrell (Griffen).

For advanced reading the following books are recommended :—*Textile Fibres* by J. M. Matthews (Wiley & Sons), *Artificial Silk* by F. Reinthaler and F. M. Rowe (Chapman & Hall), and *Wool* by S. G. Barker (H.M. Stationery Office). A very good synopsis of the linen industry is in the *Catalogue of Exhibits of the Linen Industry Research Association at the Science Museum, South Kensington, November* 1930, *to February*, 1931. Copies of this may be obtained from the Linen Industry Research Association, Lambeg, Co. Antrim, Northern Ireland. *The First and Second Reports of the Fabrics Co-ordinating Research Committee*, 1925 and 1930 (H.M. Stationery Office), deal with the testing of materials for strength and water-proofing and with the action of light and micro-organisms on fabrics and also with fire-proofing. They give a very full account of most available knowledge of the subject up to the date of publication. References to these reports, therefore, are not included

in the literature references below. An encyclopædic production is *The Textile Industries* (Gresham Publishing Co.) in eight volumes.

Those desiring to follow current advances in textile science should read the *Journal of the Textile Institute*. In this journal are published the research results of the research associations for cotton, linen, silk, wool and laundering, as well as contributions from private research workers. The journal also contains abstracts of articles from all periodicals and scientific and technical journals which are of interest to the textile industry. The majority of the literature references given below are to the Journal of the Textile Institute. This list of references does not include those given in the footnotes of the text.

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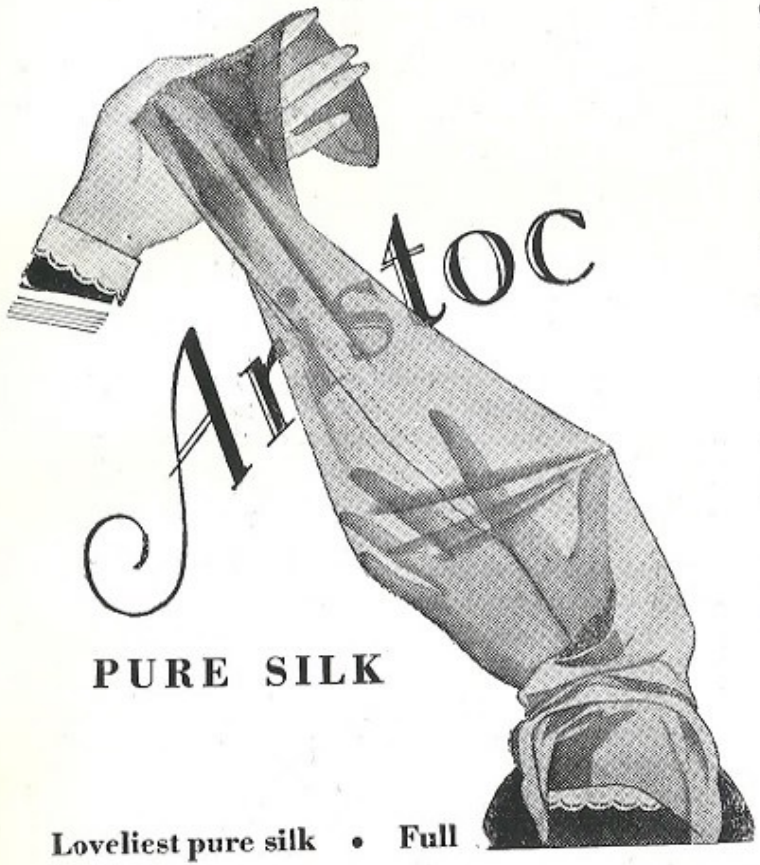

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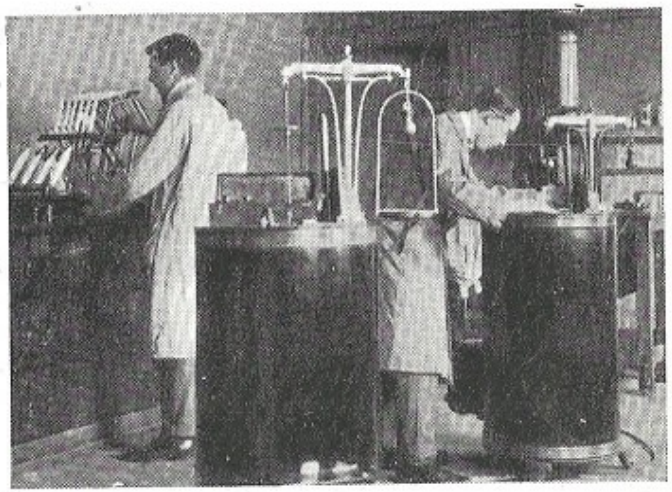

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